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The status of the Spruce Budworm in Newfoundland and Labrador in 1983–1985

A. G. Raske, L. J. Clarke, W. J. Sutton

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THE STATUS OF THE SPRUCE BUDWORM IN NEWFOUNDLAND AND LABRADOR FROM 1983 TO 1985

by A.G. Raske, L.J. Clarke and W.J. Sutton

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ABSTRACT

The productive softwood forests of Newfoundland and Labrador were surveyed from 1983 to 1985 to assess population levels of the spruce budworm (Choristoneura fumiferana (Clem.)), the effect of natural control factors on populations, to delineate and stratify subsequent defoliation, and to forecast impending outbreaks from year to year.

The area of moderate and severe defoliation increased to 68 000 ha in 1983 from 42 000 ha in 1982. The total area of defoliation, including light also increased from 91 000 ha in 1982 to 103 600 ha in 1983. Total areas of defoliation decreased drastically in 1984 to 22 600 ha and again in 1985 to 3 500 ha. In 1984 moderate and severe defoliation occurred on 15 300 ha and almost all areas of defoliation in 1985 were light.

Parasitism ranged from 3% to 30% in the years 1983 to 1985 and did not seem to be the primary factor causing collapse of populations of the spruce budworm. Mortality by fungal diseases and by microsporidia ranged from 1% to 3% by each agent in all three years.

Cumulative tree mortality had occurred on 388 700 ha of merchantable balsam fir stands in 1983 and contained a total timber volume of 40 441 000 m^3, the same as in 1982 but the dead and dying portion of this volume increased from 20 194 000 m^3 to 21 889 000 m^3. Merchantable black spruce mortality caused by defoliation by the budworm in the late 1970s and by secondary pests, bark beetles and root rots in the early 1980s occurred on 95 700 ha in 1983 with a dead and dying volume of 4 109 000 m^3 in a total stand volume of 10 322 000 m^3. Mortality rates in these stands decreased from an average of 8.7% in 1983 to 4.5% in 1984 and to 3.2% in 1985. Mortality rates in immature stands decreased from 5% in 1983 to 2% in 1984 and to 1.2% in 1985.

The Department of Forest Resources and Lands sprayed against the spruce budworm in each year from 1983 to 1985 and treated 73 380 ha, 26 336 ha and 7620 ha respectively.

RÉSUMÉ

De 1983 à 1985, des relevés ont été effectués dans les forêts de conifères productives de Terre-Neuve et du Labrador afin d'évaluer les populations de la tordeuse des bourgeons de l'épinette (Choristoneura fumiferana (Clem.)) et les effets des mécanismes de régulation biologique sur ces populations, de délimiter et de stratifier le degré de défoliation ultérieur et de prévoir d'une année à l'autre les infestations qui menacent de se produire.

La superficie des territoires où la défoliation a été modérée à sévère a augmenté, passant de 42 000 ha en 1982 à 68 000 ha en 1983. La superficie totale attaquée, y compris celle subissant une faible défoliation, a également augmenté, passant de 91 000 ha en 1982 à 103 600 ha en 1983. La superficie totale défoliée a énormément diminué en 1984 et en 1985, tombant respectivement à 22 600 et 3 500 ha. En 1984, 15 300 ha ont subi une défoliation modérée à sévère et, en 1985, presque toutes les régions attaquées n'ont subi qu'une légère défoliation.

De 1983 à 1985, le parasitime allait de 3 à 30% et n'a pas semblé le facteur premier de affraissment de population de la tordeuse des bourgeons de l'épinette. Pendant ces trois années, les maladies fongiques et les microsproidies ont chacune entraîné la mort de 1 à 3% des arbres.

En 1983, 388 700 ha de peuplements commercialisables de sapin baumier ont été anéantis par différents agents, mortalité entraînant une perte totale de 40 441 000 m^3 de bois, chiffre identique à celui de 1982, mais comprenant la portion bois mort et mourant du masse a augmenté de 20 194 m^3 à 21 889 m^3. En 1983, 95 700 ha de peuplements commercialisables d'épinette noire ont été ravagés par les infestations de la tordeuse de la fin des années 70 et les épidémies de ravageurs secondaires comme les scolytes et le pourridié du début des années 80, laissant un volume de bois mort et mourant de 4 109 000 m^3 dans un peuplement sur pied d'un volume total de 10 322 000 m^3. Le taux de mortalité de ces peuplements a dimunué, passant d'une moyenne de 8.7% en 1983 à 4.5% en 1984 et à 3.2% en 1985. Le taux de mortalité dans les peuplements immatures adiminué à 5% en 1983 à 2% en 1984 et à 1.2% en 1985.

Le ministère des Ressources forestières et des Terres a appliqué des programmes de pulvérisation aérienne de 1983 à 1985 pour lutter contre la tordeuse des bourgeons de l'épinette, et appliqué 73 380 ha, 26 336 ha et 7 620 ha respectivement.

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V. ACKNOWLEDGEMENTS

We gratefully acknowledge the cooperation of the Newfoundland and Labrador Department of Forest Resources and Lands in providing the Forest Insect and Disease Survey, Canadian Forestry Service with aircraft, part-time assistance and forest inventory figures. We are grateful to the Newfoundland Department of the Environment who kindly provided pre-published manuscripts of their environmental monitoring reports of the spruce budworm spray program enabling us to make this report complete by including summaries of their findings.

We thank the FIDS field and laboratory technicians: E.C. Banfield, D.S. O'Brien and D.M. Stone and K.E. Pardy, who made a major contribution to this report through their observations, aerial mapping and procurement of data. We thank E.J. Dobesberger for the use of his budworm population data and K.P. Lim for the use of larval-mortality data. Special thanks are due to D.M. Stone who prepared the figures used in this report. Typing of the manuscript by H. Dunphy and M.F. Gillingham is gratefully acknowledged.

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I. INTRODUCTION

Populations of the eastern spruce budworm, Choristoneura fumiferana (Clem.), have continued to decrease from 1983 to 1985, although pockets of infestations remained that caused severe defoliation. The outbreak in Newfoundland was most severe in 1978 and 1979 and was part of a major outbreak affecting much of eastern North America reaching west to Manitoba and Minnesota. In Newfoundland, balsam fir, Abies balsamea (L.) Mill., has been extensively damaged and black spruce, Picea mariana (Mill.) B.S.P., has also sustained considerable mortality.

This report is the seventh in a series on the status of the spruce budworm outbreak in Newfoundland published by the Newfoundland Forestry Centre. The first summarized all known outbreaks and documented the latest outbreak to 1977 (Otvos and Moody 1978), and the others have been annual updates of the current outbreak (Moody and Otvos 1979; Moody 1980; Raske and Clarke 1982; Raske et al. 1986). Two reports described methods of assessing damage (Moody 1979; Sutton 1981). This report presents results of spruce budworm surveys in the years 1983 to 1985, including maps of the annual forecast and hazard levels for each of these years. Updates of survey methods used have been described primarily by Raske and Clarke (1982), Raske et al. (1982) and Raske et al. (1986).

II. THE SPRUCE BUDWORM IN 1983

A. Outbreak Details

a) Host Condition at the Beginning of 1983

The area of moderate and severe defoliation decreased considerably in 1982 and no new areas of defoliation occurred. However, tree mortality in black spruce areas increased and the proportion of tree mortality within existing damaged balsam fir areas increased in 1983. At the beginning of 1983 the total area with more than 10% tree mortality was about 469 000 ha containing a total stand volume of 48 674 000 m^3. The dead and dying portion of this stand volume was about 22 660 000 m^3.

The lack of further defoliation in many areas in 1982 provided a year for recovery. However the rapid mortality and decrease in vigor of black spruce started in the fall of 1982 and posed a serious threat to black spruce stands of the Island.

b) Forecast of Budworm Infestation for 1983

The forecast of severity of budworm infestation and its extent for 1983 was based on 822 sample points across the Island and 20 points in Labrador. About 113 of these samples were also washed for overwintering larvae to supplement the results of the egg-mass survey by refining boundaries of areas forecast to be infested. All branches checked for egg masses were rechecked by a second person.

The area of moderate and severe defoliation was forecast to be about 110 300 ha and an additional 102 000 ha were forecast to have light defoliation for a total of 212 300 ha (Fig. 1). The area forecast for 1983 was about twice as large as the 91 000 ha defoliated in 1982. The areas of moderate to high hazard were forecast to be 165 000 ha in 1983 on the island and about 1 000 ha in Labrador (Fig. 2).

c) Larval Development in 1983

In 1983 spring and summer weather were warmer and dryer when compared to the long-term average and also compared to 1982. Larval development was ahead of the average and about three weeks ahead of 1982. For the third year in a row shoot growth was ahead of larval development. Moth emergence began by 4 July, about two weeks earlier than in other years.

The average number of budworm larvae per sample in infested areas has been reported for each year since 1977. After a steady decrease for the last five years, the average number increased in 1983 (Appendix VII). For beating samples, budworm larvae averaged 4.8 in 1983, up from 3.3 in 1982. For branch samples the average increased to 8.8 from 2.8.

d) Natural Control Factors

Spruce budworm larvae and pupae were sampled throughout the island in 1983 by Forest Insect and Disease Survey rangers to determine rates of parasitism and the prevalence of diseases. Adult emergence from these samples was about 70%, about 3% were parasitized and 26% died of either disease or of an unknown cause (Table 1). Results of larvae reared for research purposes were 10% parasitized, 1% killed by fungal diseases and 3% contained the microsporidian disease Nosema fumiferanae (Thom.). Total parasitism of 10%, obtained from the research plots, was about the same as the 11% recorded for 1982 and 8% for 1981 recorded at the research plots. Apanteles fumiferana (Vier.) and Glypta fumiferanae (Vier.) continued to be the dominant larval parasite species, and Phaeogenes hariolus (Cress.) and Ephialtes ontario (Cress.) the dominant pupal parasites.

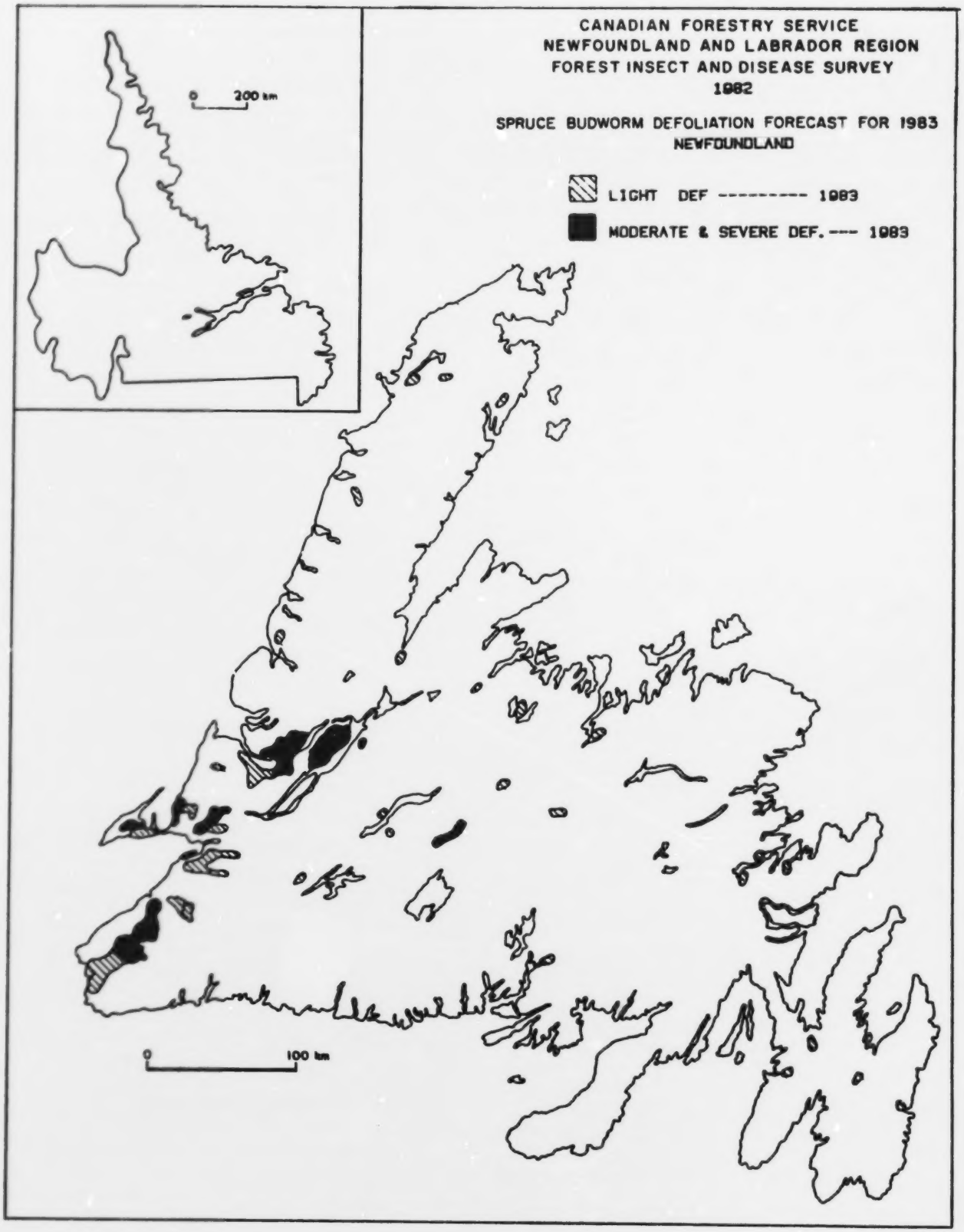

Figure 1. Areas of light, moderate and severe spruce budworm defoliation forecast in Newfoundland and Labrador for 1983.

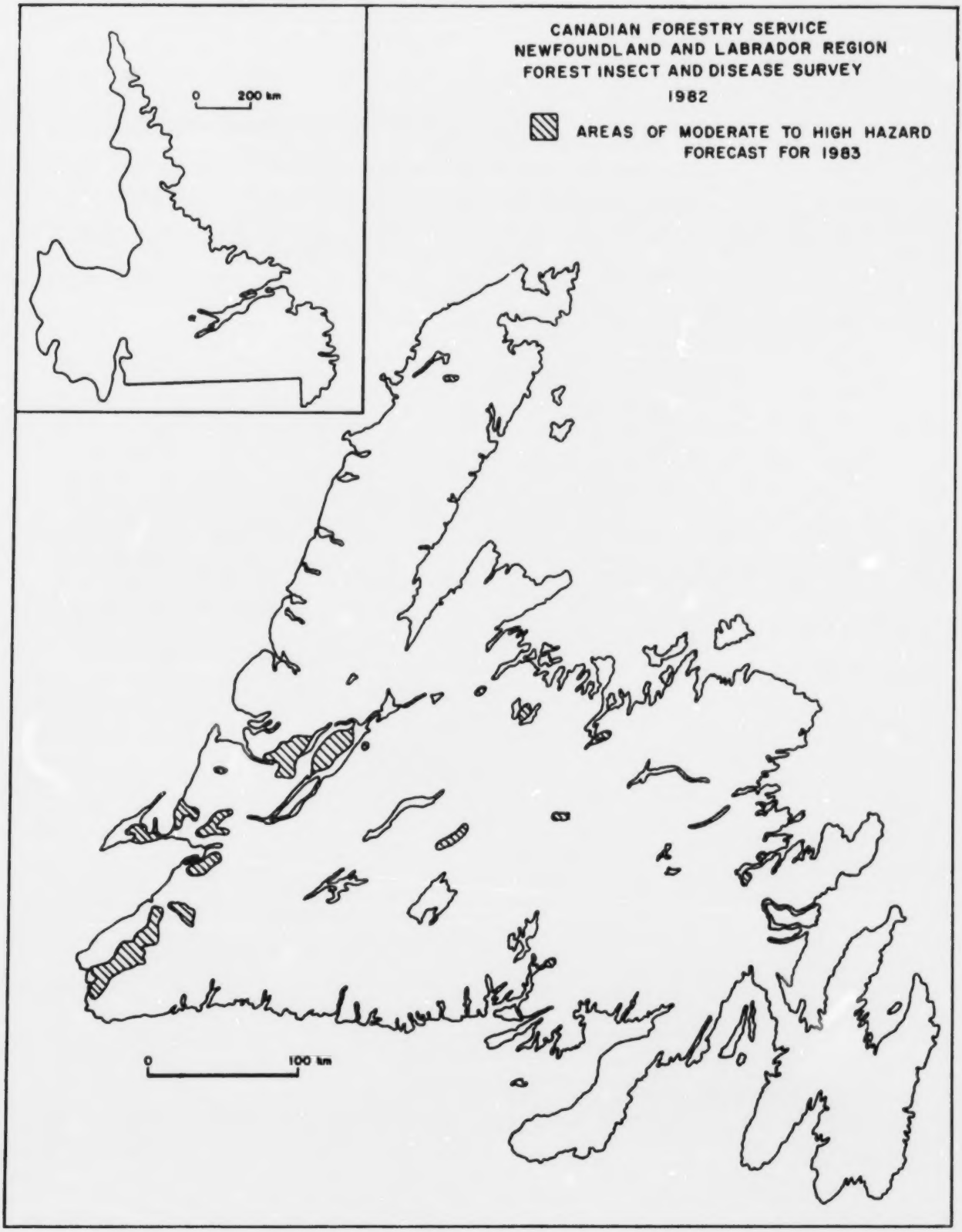
CANADIAN FORESTRY SERVICE
NEWFOUNDLAND AND LABRADOR REGION
FOREST INSECT AND DISEASE SURVEY
1982
AREAS OF MODERATE TO HIGH HAZARD FORECAST FOR 1983
0 200 km
0 100 km

Figure 2. Areas of moderate to high spruce budworm hazard forecast in Newfoundland and Labrador for 1983.

Table 1. Results of FIDS spruce budworm rearings in 1983 in Newfoundland.

FIDS district	Total no. reared	No. moths emerged	No. parasitized	No. missing or death by misc.	No. diseased and dead by unknown causes
Bonavista	37	25	0	0	12
Humber	197	135	7	0	55
St. Barbe	40	33	1	0	6
White Bay	30	22	1	4	3
St. George's	219	150	8	0	61
Total	523	365	17	4	137
% of Total		70%	3%	1%	26%

Fungal infection, mainly by Zoophthora radicans (Bref.) was less than 1% in 1983, down from 12% in 1982 and the same as 1% in 1981. The incidence of the microsporidian disease at 3% of the larvae did not change from 1982 when it was 2%.

e) Moth Flight

Traps baited with budworm sex pheromone were placed in the forests of western and central Newfoundland to detect invasion of moths from the Maritime Provinces or Quebec. However, moth emergence in Newfoundland began in early July, the same dates as in adjacent provinces and no conclusion regarding moth invasion could be drawn.

f) Defoliation Estimates

The annual aerial survey for spruce budworm defoliation began in mid-July in 1983, two weeks earlier than in 1982. Defoliation classes of light, moderate and severe were the same as in recent years. The total area of light, moderate and severe defoliation in the productive forests of the Island was about 103 200 ha in 1983 (Table 2), up by about 12 000 ha from 91 000 ha recorded in 1982. The total area of defoliation was about half of that forecast and the moderately and severely defoliated areas about 70% of that forecast. However, the area of moderate and severe defoliation increased from 42 000 ha in 1982 to about 68 000 ha in 1983.

Comparing the defoliation maps of 1982 and 1983 (Figs. 3 & 4) the increase in 1983 occurred in all areas of defoliation except the area near Stephenville. Areas of defoliation increased in southwestern Newfoundland, around the Bay of Islands, between Deer Lake and Grand Lake, in the Northern and Baie Verte Peninsulas, Noel Paul's Brook and a small area on the Bonavista Peninsula.

Table 2. Area (ha) of defoliation caused by the spruce budworm in productive forests of Newfoundland in 1983.

Management Unit No.	Defoliation Class[1]			
	Light	Moderate	Severe	Total
2	300	-	-	300
9	2 600	-	2 200	4 800
10	300	-	-	300
11	-	-	200	200
12	1 700	-	4 200	5 900
14	11 700	2 700	34 100	48 500
15	15 500	1 400	22 400	39 300
16	2 200	-	200	2 400
17	200	-	-	200
18	1 300	-	-	1 300
Total Island	35 800	4 100	63 300	103 200
Labrador	100	-	300	400

[1]Light - 1-25%
Moderate - 26-75%
Severe - 76-100%.

In Labrador two small infestations, one near Goose Point and the other along the Beaver River, declined to 400 ha in 1983, but continued to exist.

B. Damage Assessment

a) Mortality

The 1983 damage assessment was again a cooperative effort between the Newfoundland Forestry Centre of the Canadian Forestry Service and the Newfoundland Department of Forest Resources and Lands (DFRL). Methods of estimating areas and volumes of spruce budworm damaged timber from 1974 to 1977, and the improvements introduced in 1978, 1980 and 1981 have been published (Moody 1979; Raske and Clarke 1982; Raske et al. 1982). To date the basic method consists of delineating damaged areas by percent mortality classes on topographic maps (scale 1:50,000) during a survey by helicopter and then transferring these boundaries to forest inventory maps (scale 1:30,000) or to the most recent colored aerial photographs (scale 1:12,500) and applying the percent mortality figure from aerial and ground surveys. All productive forests were surveyed

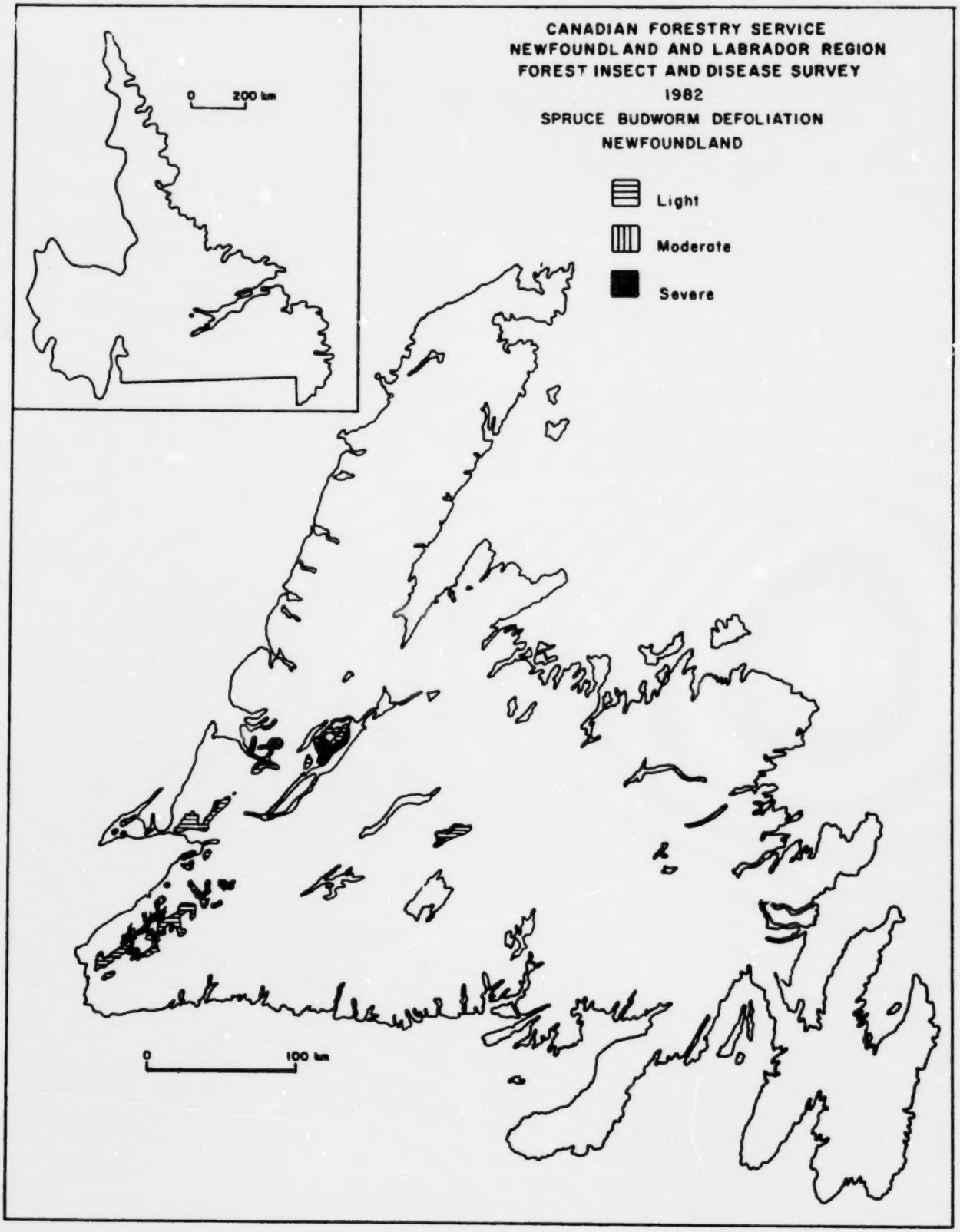

Figure 3. Areas of light, moderate and severe spruce budworm defoliation in Newfoundland and Labrador for 1982.

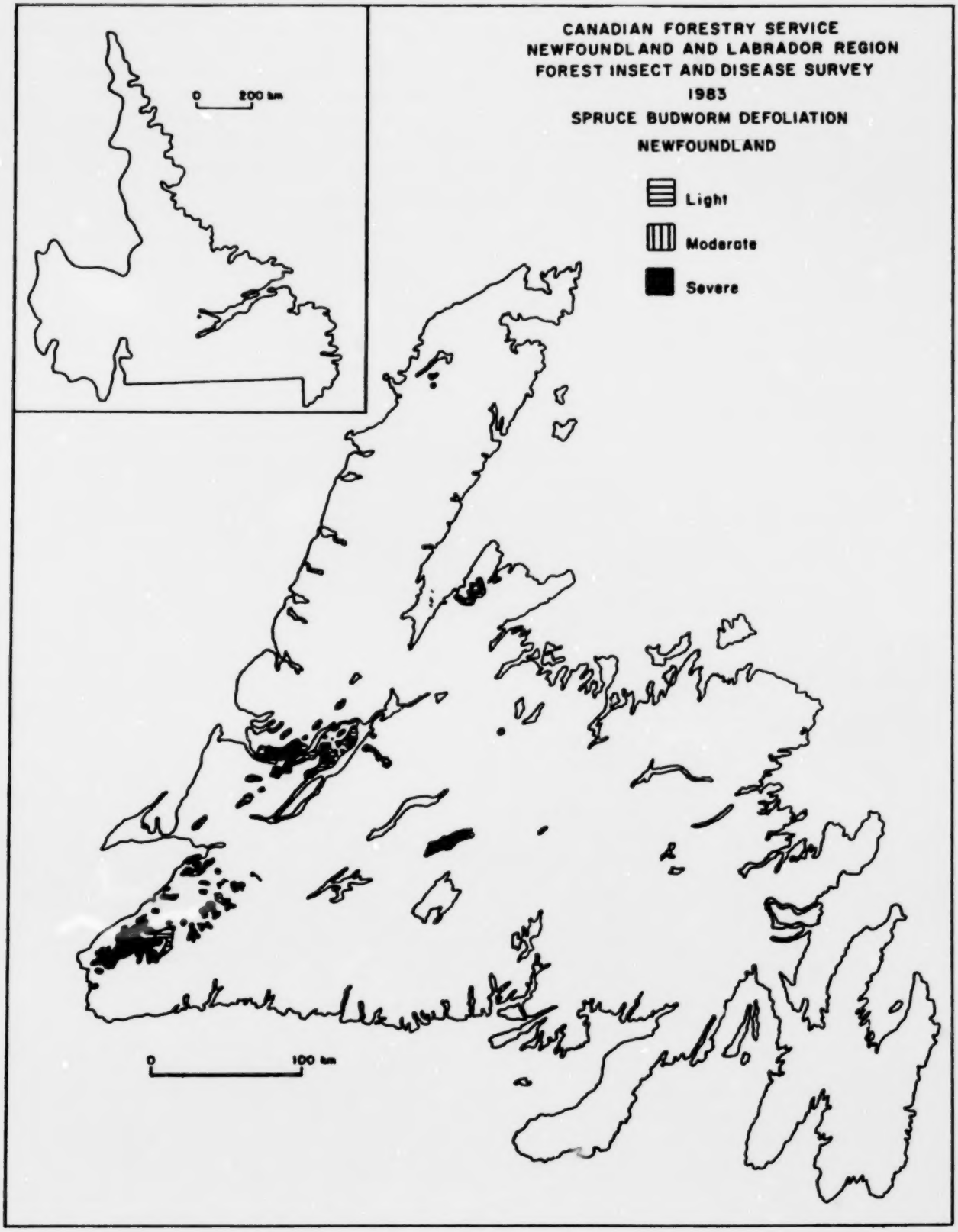

Figure 4. Areas of light, moderate and severe spruce budworm defoliation in Newfoundland and Labrador for 1983.

from the air but ground sampling was concentrated in predominantly black spruce stands in central and eastern Newfoundland where increased stand deterioration and tree mortality had occurred since 1982.

The comprehensive analysis of the 1983 damage assessment by the DFRL has not been published but preliminary results by the Canadian Forestry Service indicate that the area of damaged merchantable balsam fir stands did not increase appreciably from the 388 700 ha recorded in 1982 (Table 3). However, the proportion of tree mortality in predominantly fir stands increased from 19 074 000 m^3 in 1982 to 19 905 000 m^3 in 1983 and the volume of dying trees from 1 120 000 m^3 to 1 984 000 m^3. The total volume of these stands was estimated at 40 441 000 m^3 (Fig. 5, Table 3).

Table 3. Cumulative area and volume of balsam fir and black spruce stands with more than 10% tree mortality following spruce budworm defoliation in Newfoundland by 1982 and 1983.

Parameters		1982	1983 (estimate)
Merchantable balsam fir stands			
Total area	ha	388 700	388 700
Dead volume	m^3	19 074 000	19 905 000
Dying volume	m^3	1 120 000	1 984 000
Total stand volume	m^3	40 441 000	40 441 000
Merchantable black spruce stands			
Total area	ha	80 500	95 700
Dead volume	m^3	2 002 000	3 194 000
Dying volume	m^3	464 000	915 000
Total stand volume	m^3	8 233 000	10 322 000
Merchantable balsam fir stands and black spruce stands combined			
Total area	ha	469 200	484 400
Dead volume	m^3	21 076 000	23 099 000
Dying volume	m^3	1 584 000	2 899 000
Total stand Volume	m^3	48 674 000	50 763 000

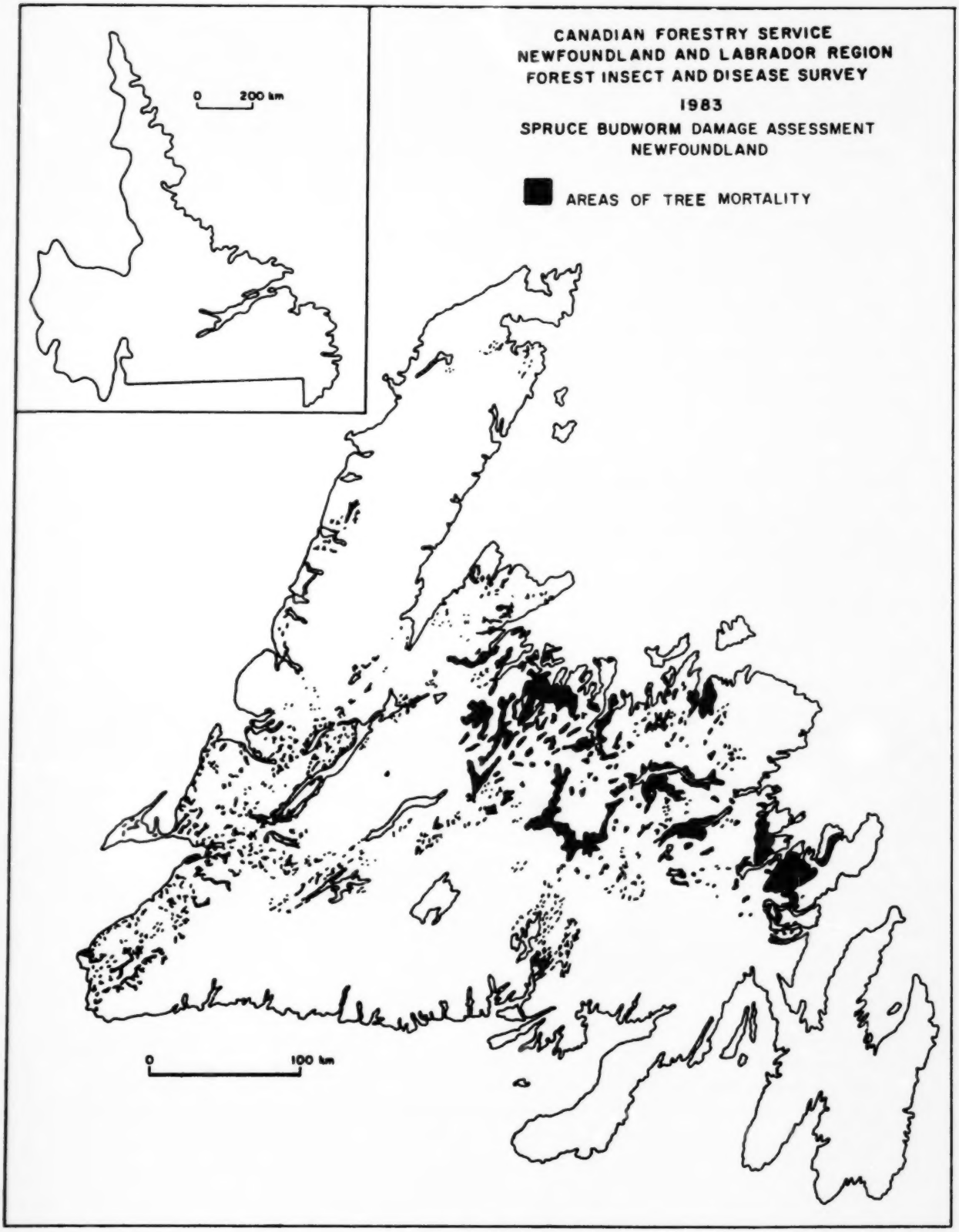

Figure 5. Areas of balsam fir and black spruce tree mortality following spruce budworm damage and attack by secondary pests in Newfoundland and Labrador in 1983.

The general deterioration and increased tree mortality that began in the fall of 1982 in predominantly black spruce stands of central Newfoundland continued in 1983 (Fig. 6). The most noticeable increase occurred in the Hall's Bay and Twin Lakes region where isolated areas of mortality coalesced. The areas of tree mortality also increased and coalesced in the Northwest Gander River Valley. The area of black spruce stands with more than 10% dead and dying trees increased from 80 500 ha in 1982 to about 95 700 ha in 1983 (Table 3). The volume of dead trees increased from 2 002 000 m^3 to 3 194 000 m^3 and the volume of dying trees from 464 000 m^3 to bout 915 000 m^3. The total volume of these stands was estimated at 8 233 000 m^3 in 1982 and about 10 322 000 m^3 in 1983. In addition dead and dying trees comprising less than 10% of the stand volume was recorded on 100 000 ha in 1983 (Fig. 5). Assuming an average volume of 100 m^3/ha the total volume of these stands is estimated at 10 000 000 m^3.

In summary the combined area of balsam fir stands and black spruce stands with more than 10% mortality increased from 469 200 ha in 1982 to 484 400 ha in 1983 and the volume of these stands increased from 48 674 000 m^3 in 1982 to 50 763 000 m^3 in 1983 (Table 3). The volume of dead and dying trees at 25 998 000 m^3 comprised more than 50% of the volume of these stands.

Not all of these cumulative volumes killed by the spruce budworm exist at present because harvesting operations have been concentrated in salvaging. Forest fires, windthrow and advanced decay also have decreased the amount of dead and dying volumes. An estimated 5 624 000 m^3 have been salvaged by 1983, 562 000 m^3 has burnt, 6 422 000 m^3 has blown down, and 4 050 000 m^3 is beyond salvage because of advanced decay (Appendix VII).

The large areas of immature stands damaged by the spruce budworm did not change in size from 1982 to 1983. A total of 64 800 ha of trees had been severely damaged by 1982. About half of these young stands contained almost complete tree mortality, and therefore will require stand reclamation to return them to softwood production in the near future.

b) Causal Factors of Black Spruce Mortality

All black spruce stands with tree mortality in central Newfoundland had been severely defoliated by the spruce budworm for several years prior to 1980 which resulted in some tree mortality and widespread top kill. However, following the decline of budworm populations most of the stands showed good recovery for two to three years until the fall of 1982 when the general stand deterioration began. Good recovery was evidenced by the large number of new shoots produced and by the increased length of terminal branch shoots in 1981 and 1982 (Raske and Sutton 1986) and new leader formation. There appeared to be no decline in vigor.

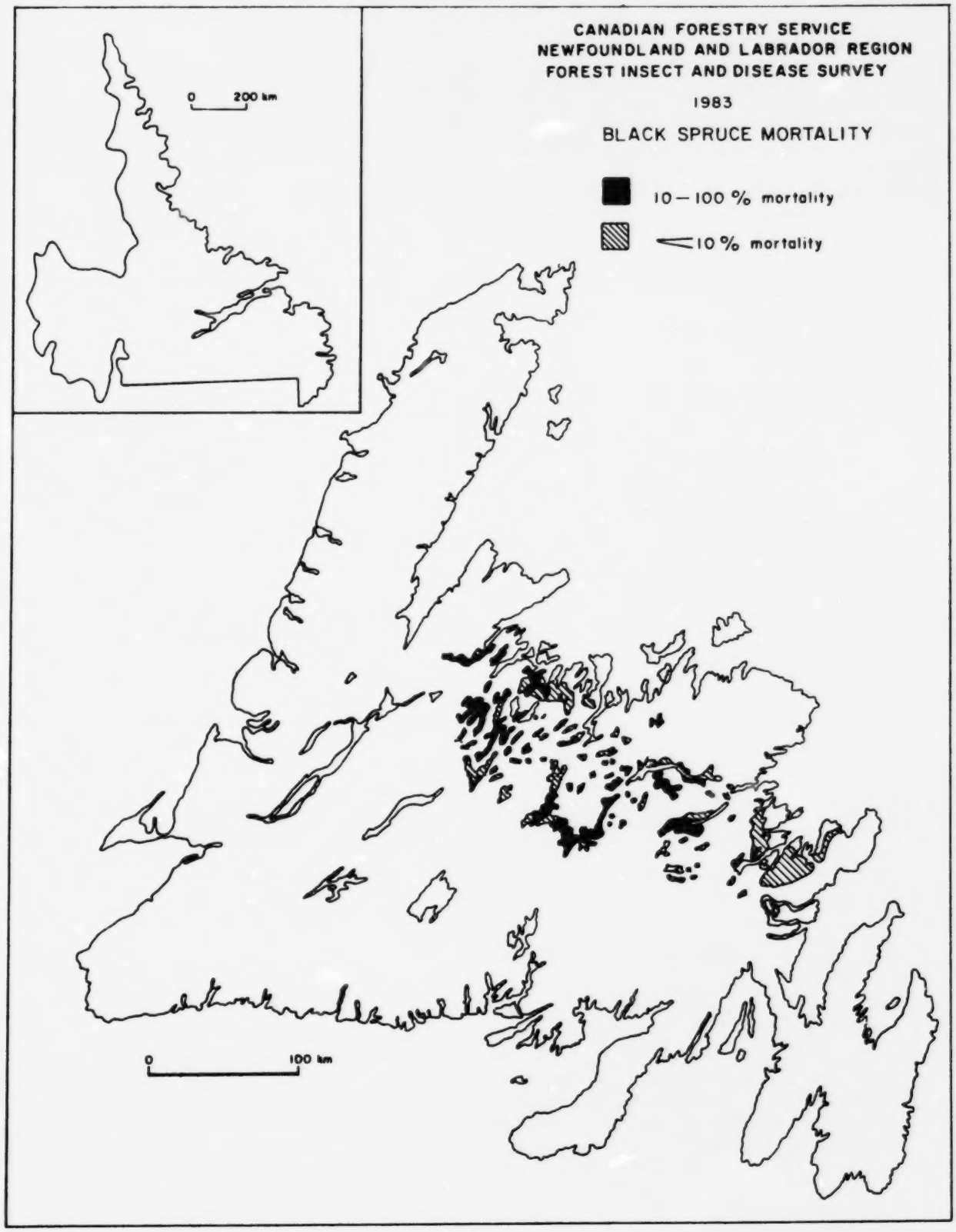

Figure 6. Areas of black spruce mortality following spruce budworm damage and attack by secondary pests in Newfoundland and Labrador in 1983.

In early October of 1982 the inner foliage of many spruce trees turned yellow and then bright red-brown and dropped suddenly by mid-October. These spruce trees were left with a shell of green foliage of the two most recent years. The loss of inner foliage made the black lichens, common in the crowns of black spruce, visible, giving the trees and stands a black hue. In many trees the loss of inner foliage was accompanied by rapid branch mortality and then tree mortality. The general decline in living crowns and tree mortality continued in 1983. In the fall of 1983, the same loss of inner foliage, with similar symptoms, occurred in trees not so affected in 1982. In October 1983 affected trees were not nearly as abundant as in 1982 and most occurred on the east coast, an area not as severely hit with spruce decline in 1982 (Raske and Sutton 1986).

The four-eyed spruce bark beetle, Polygraphus rufipennis Kirby, had been present in most trees that had died before 1982 in severely damaged areas. However, in 1982 the beetle was found attacking and successfully establishing broods under the bark of trees with various amounts of green foliage on them. Thus, the bark beetle seemed to enhance the rate and extent of tree mortality. Duplicate sample plots were established in the fall of 1982 to monitor beetle activity and tree mortality in stands with light, moderate and severe budworm damage located in the South Brook River watershed and in the Northwest Gander River watershed. The pattern of beetle attack continued in 1983 and spruce mortality was measured in the 12 permanent plots established in 1982. Data was combined by area and degree of cumulative budworm damage. Mortality in 1983 was 3% of living spruce in light damage areas, 13% in moderate damage areas, 10% in severe damage, and 5% in a young stand. Most of this mortality (78%) was concentrated in trees with crown mortality of 80% or more. But 17% occurred in trees with crown mortality of 50% or less, which included several trees with no apparent crown mortality.

The severity of the root rot fungus, Armillaria sp. (mellea complex) was examined by exposing the root systems of 192 black spruce trees with water sprayed from fire hoses. Trees were grouped by degree of cumulative crown mortality. Armillaria was present in the roots of black spruce with crown mortality of 0% to 80% at a level of 9% to 30% of the trees sampled (Table 4). This may be the normal level within trees recently stressed by defoliation. However, 85% of trees had Armillaria in the roots when crown mortality was over 80%. Similar relationships existed for the extent of Armillaria in the roots and in the root collar. The percent of cambial root surface covered with Armillaria mycelium was 10% or less in trees with crown mortality of 80% or less, but increased to 75% in the most severe damage category. In the cambial region of the root collar relatively little Armillaria occurred below 80% crown mortality, but in 64% of the cambial surface at crown mortalities greater than 80% (Table 4). Thus, Armillaria seems to invade rather quickly when trees are stressed and to contribute to tree mortality of these trees.

Table 4. Incidence and extent of Armillaria sp. (mellea complex) infection in root systems of spruce budworm damaged black spruce in Newfoundland in 1983.

Cumulative crown mortality	No. trees sampled	% Trees with Armillaria	Total root surface examined (cm^2)	% Root surface with Armillaria	Total root collar surface examined (cm^2)	% Root collar surface with Armillaria
0-20	58	8.6	3756	0.7	539	0.0
21-40	36	19.4	2935	6.9	475	13.1
41-60	37	29.7	4132	6.1	572	3.5
61-80	28	25.0	3234	10.5	434	2.4
81-100	33	84.8	2084	75.5	267	63.9

Incidences of the root collar weevil, Hylobius warreni Wood, was recorded in the exposed root systems of all 192 trees. An average of 21% of the trees in the 2-20% defoliation had Hylobius damage at the root collar, 36% at 21-40% defoliation class, 43% at the 41-60% class and 57% and 39% at the next two higher defoliation classes. The incidence of Hylobius weevil damage had a tendency to increase with defoliation damage. However, observations on the severity of weevil damage indicated that this weevil did not contribute significantly to black spruce mortality.

Acid rain and the wood nematode, Bursaphelenchus xylophilus (Steiner and Buchrer), were also considered as possible factors in the mortality of black spruce. However, no evidence could be found for their presence or their influence and it was concluded that these factors played no role in the sudden mortality of black spruce in Newfoundland.

C. THE SPRUCE BUDWORM SPRAY PROGRAM

a) Spray Operations

The Newfoundland Department of Forest Resources and Lands (DFRL) sprayed a total of 73 380 ha of forest to prevent damage by the spruce budworm (Fig. 7). A total of 99.2% of the area sprayed received a double application with aminocarb (= Matacil), the remainder a single application. About 1 500 ha were to be sprayed with B.t. (Thuricide 16B) but these were deleted for lack of significant budworm populations (Carter 1984).

Pre-spray population levels were very variable between and within spray blocks. Some areas were deleted because of low larval counts, but other areas had 40-70 larvae per 45 cm branch tip.

A standard dosage of 70 g ai/ha was sprayed at the rate of 1.46 ℓ/ha for each application. Spraying was done by a team of four AgCats and by one DC-6 with all planes equipped with standard boom and nozzle with Tee Jet tips. Spraying began on 6 June and was completed by 26 June.

The success of the spray operation was difficult to judge because of the large variability in larval numbers within spray blocks. Corrected larval mortality ranged from 73-100% and averaged 84% for the Island. Foliage protection ranged from 15-40% per spray block and averaged 35%. Aerial estimates of defoliation of sprayed areas resulted in 89% being classed as light, 10% as moderate and only 1% as severe (Carter 1984).

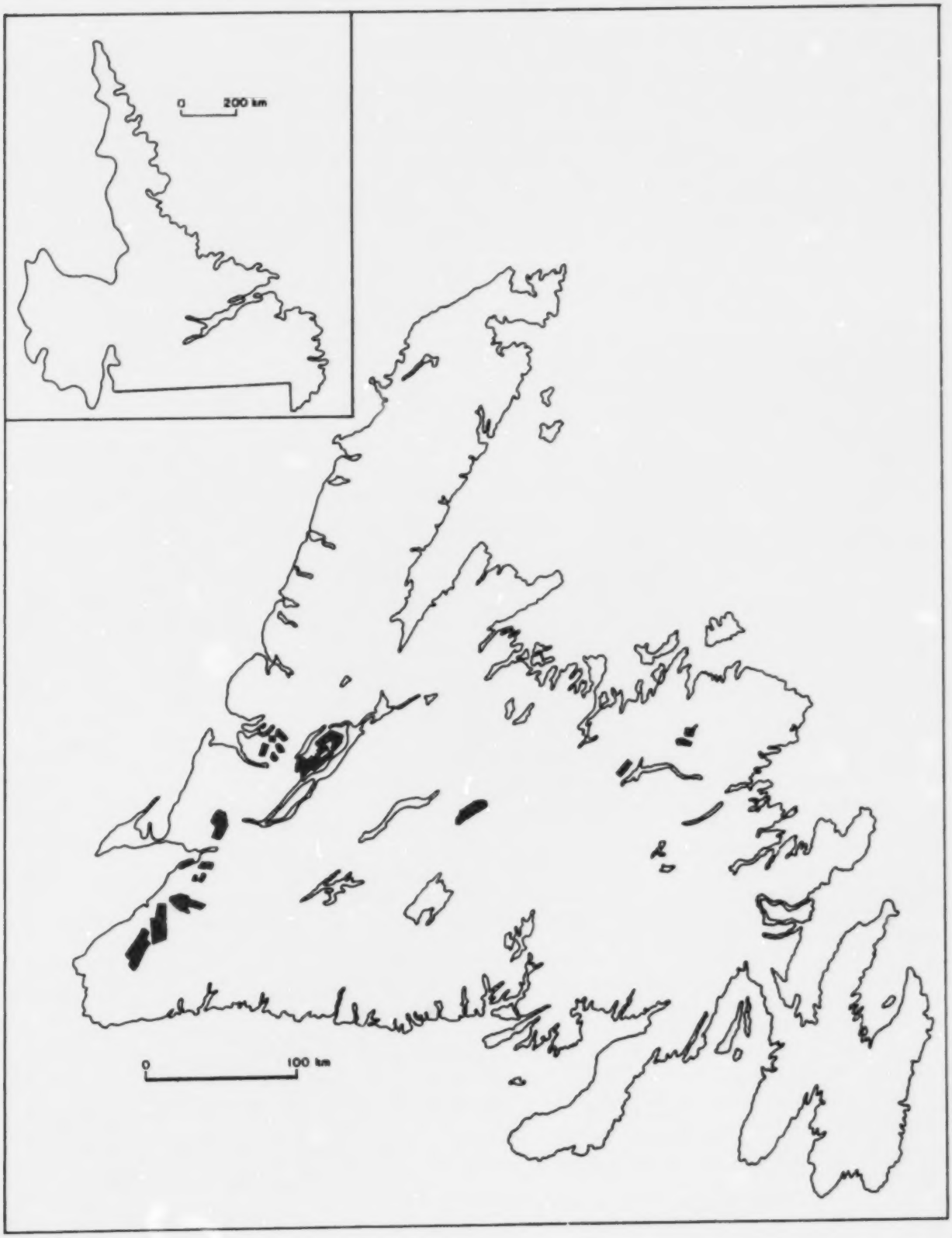

Figure 7. Areas sprayed against the spruce budworm in Newfoundland in 1983.

b) Environmental Monitoring

Environmental monitoring in 1983 consisted of determining Matacil residues in sprayed and unsprayed areas, evaluating differences in bird abundance, measuring bird blood-parasite levels, and measuring biomass of some components of aquatic communities (Anon. 1986a).

Similar to past years results, Matacil could not be detected in flowing waters 24 to 36 hours after the spray. In other parts of the environment, Matacil could not be detected after the first application in unsprayed areas nor in two of the three samples in the sprayed area. Following the second application, Matacil residues were detected in all samples from the sprayed area.

Bird communities did not differ between sprayed and control areas. The rate of capture of adults banded in 1982 and captured in nets in 1983 also did not differ significantly between sprayed and unsprayed areas, nor did the capture rate of birds banded in 1982 as immatures. However, the rate of repeat capture of birds caught in nets at least once previously in 1983 was 15% in the control area, 10% in one sprayed area and 27% in the other sprayed area. Possibly the bird population was less stable in the latter area.

Blood smears were taken from 1,852 birds and checked for the presence of two parasite species. The rate of parasitism did not differ in birds from sprayed and unsprayed areas for adult birds. Unexpectedly, immature birds had a lower incidence of parasites in the unsprayed area. However, the reason for nor the significance of this is not known (Anon. 1986a).

Macro-invertebrates in streams were measured in dry weight biomass, which removed much of the "background noise" of previous studies. Drift of insects in streams estimates short term spray impact of lethal and sublethal effects. Estimates of stream bottom dwellers evaluate impact on intermediate spray effects in the form of biomass available for fish food. Algal data permits measures of long term spray impact as algae constitute a major food supply for small insects and for the organisms that insects feed on.

Seasonal pattern of drift were similar in magnitude and timing in both sprayed and unsprayed streams. These results are the same as in 1982.

There was no evidence of an immediate decrease in levels of biomass of macro-invertebrates on stream bottoms in sprayed streams.

However, biomass levels in both sprayed streams was lower throughout the season compared to those in the two unsprayed streams, but less so than in 1982. This suggests that the streams sprayed for three consecutive years are becoming more like the unsprayed streams despite continued spraying and they are not deteriorating with time. Also it is not known what levels of biomass were present in the streams before spraying. In 1984 one of the sprayed streams will not be sprayed and one of the control streams will be sprayed. This may resolve some questions regarding initial spray impact on streams.

There was no apparent effect of Matacil spray on algal biomass in sprayed streams.

D. FORECAST OF BUDWORM INFESTATIONS FOR 1984

In addition to branch samples collected in the fall for egg-masses, pheromone traps had been placed in late June in western and central Newfoundland. These traps caught numerous moths in areas of defoliation. However, traps away from defoliated areas, especially in central Newfoundland caught only one to two moths per trap indicating low population levels.

Spruce budworm egg-masses were surveyed by collecting branches from 635 points across the Island and 15 points in Labrador. The branches at 89 sample points were also washed in a sodium hydroxide solution for overwintering larvae to refine boundaries of infestations. All samples were checked by a second person.

The area of light, moderate and severe defoliation on the Island is forecast to be about 135 600 ha for 1984 (Table 5). Moderate and severe defoliation is expected to be about 55 200 ha distributed along the north branch of the Codroy River, near Corner Brook, Hughes Brook, Pasadena-Grand Lake and Noel Paul's Brook (Fig. 8). Light defoliation is forecast to occur on 80 400 ha on the Island near Mummichog Provincial Park, throughout the Codroy Valley to Robinson's River, near Glenburnie, St. Paul's Inlet, Parsons Pond, Sandy Lake to Birchy Basin, Middle Arm to Wild Cove, Harbour Round Pound (Red Indian Lake) and Exploits River near the mouth of Noel Paul's Brook (Table 5, Fig. 8).

The area of defoliation forecast for Labrador is about 1 500 ha of which 1 100 ha is forecast to be in the moderate and severe category (Table 5). The two infestations remain along the Beaver River and the other near Goose Bay.

Table 5. Areas (ha) of light, moderate and severe defoliation and areas of moderate to high hazard forecast in productive forests by the spruce budworm in Newfoundland for 1984.*

Management unit no.	Ownership	Defoliation Category[1] Light	Moderate and severe	Totals	Moderate to high hazard
2	Crown	800	-	800	-
9	Bowater	11 700	-	11 700	-
12	Abitibi-Price	3 000	11 000	14 000	11 000
14	Crown	10 700	-	10 700	7 400
14	Bowater	17 600	1 800	19 400	18 600
15	Crown	-	12 900	12 900	12 900
15	Bowater	4 600	29 500	34 100	24 500
16	Bowater	8 400	-	8 400	-
17	Crown	2 100	-	2 100	-
17	Bowater	18 000	-	18 000	-
	GMNP	3 500	-	3 500	-
	Crown	13 600	12 900	26 500	-
All	Bowater	60 300	31 300	91 600	-
	Abitibi-Price	3 000	11 000	14 000	11 000
	GMNP	3 500	-	3 500	-
Total Island		80 400	55 200	135 600	79 300
Total Labrador		500	1 100	1 500	1 500
Total Province		80 900	56 300	137 100	80 800

*Forecast based on egg-mass and overwintering larvae surveys.

[1]Light - 1-25%
Moderate - 26-75%
Severe - 76-100%.

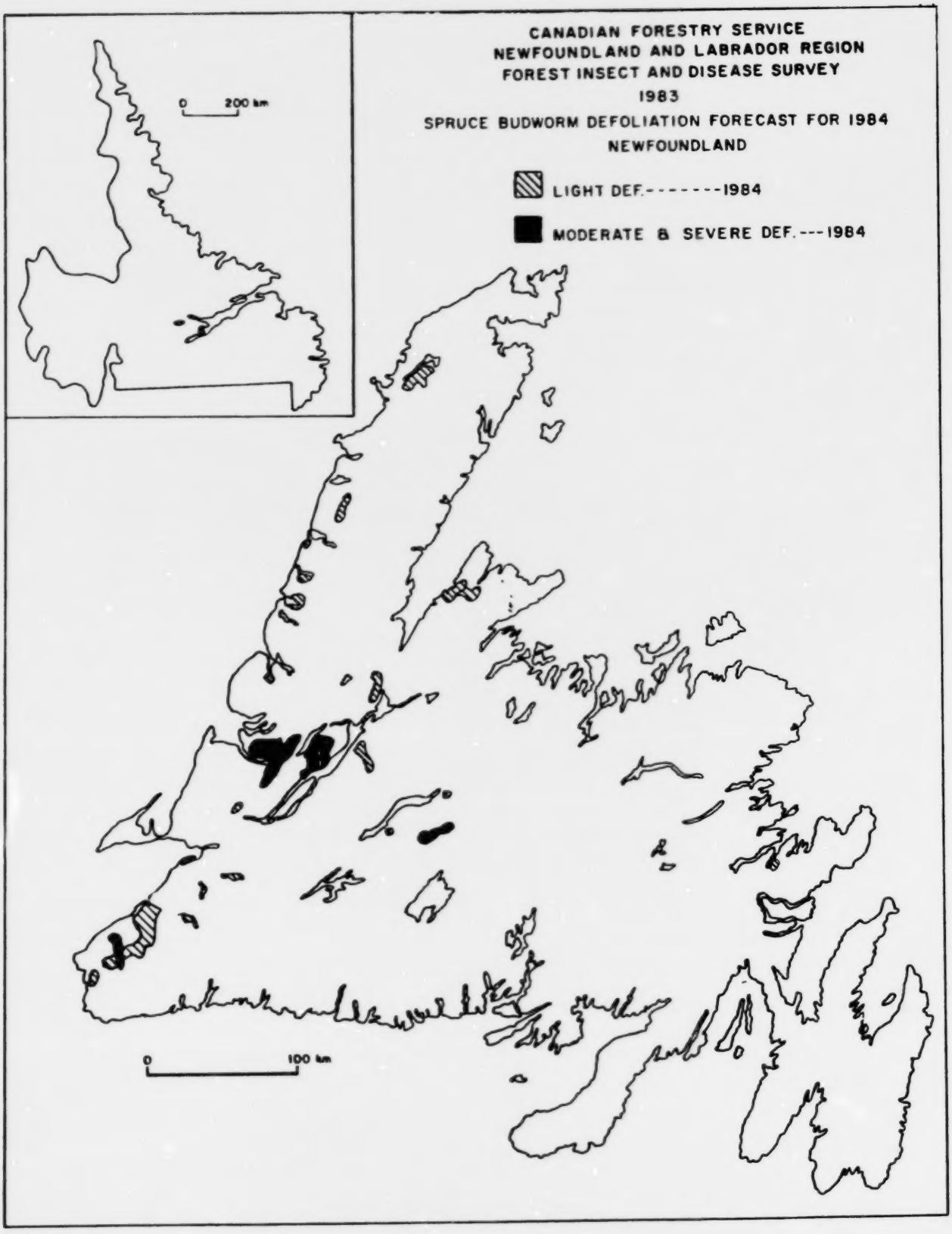

Figure 8. Areas of light, moderate and severe spruce budworm defoliation forecast in Newfoundland and Labrador for 1984.

Moderate to high hazard, based on tree condition and expected defoliation, is forecast to occur on about 80 000 ha on the Island and on 1 500 ha in Labrador (Fig. 9). The total area of light, moderate and severe defoliation forecast (135 600 ha) is about 32 000 ha more than the total area of defoliation in 1983 (103 200 ha), indicating that the outbreak has the potential of holding its own in 1984.

A total of 95% of the branch samples had no egg-masses and 45% had no overwintering larvae in 1983, and 97% of the samples occurred in areas forecast to have nil or light defoliation. In 1982 the proportion of samples without egg-masses was 91% and it was 89%, 56%, 57%, 51% and 31% in 1981 to 1977 respectively.

The average number of egg-masses per 10 m^2 of all localities has been used as an index of spruce budworm population levels (Table 12). This index, averaged for all regions, was greater than 90 before 1980, but dropped to 14 in 1981, to 7 in 1982 and was 4 in 1983. Even those sample locations with sufficient egg-masses to forecast moderate and severe defoliation were few, they had slightly less egg-masses per 10 m^2 of foliage in 1983 than in previous years (Table 13).

E. SUMMARY AND CONCLUSIONS FOR 1983

A total of 212 300 ha was expected to be defoliated in 1983 in Newfoundland of which 165 000 ha was in the moderate to high hazard category. Warm and dry weather predominated in early June, and larval development was three weeks earlier compared to 1982 and 1981.

Combined larval and pupal parasitism was about 3% in one set of samples and 10% in another set. About 1% were killed by fungal disease, and 3% contained sporidia at time of death. Adult emergence from budworm samples was about 70%.

The total area of light, moderate and severe defoliation in productive forests of the Island was about 103 200 ha, of which 67 000 ha were in the moderate and severe categories.

The total area of merchantable stands containing more than 10% tree mortality was 484 400 ha of which 388 700 ha was balsam fir and 95 700 ha was predominantly black spruce. Stands in this total area contained a total volume of 50 763 000 m^3, of which 40 441 000 m^3 was balsam fir and the remainder 10 322 000 m^3 black spruce. These stands contained 23 000 000 m^3 of dead and 2 900 000 m^3 dying trees. The volume of dead and dying trees exceeded 50% of the total stand volume.

A total of 73 380 ha were sprayed with Matacil in 1983. Good larval reductions were obtained, but foliage protection ranged from 15% to 40%. Environmental monitoring of the spray operation detected no deleterious side effects.

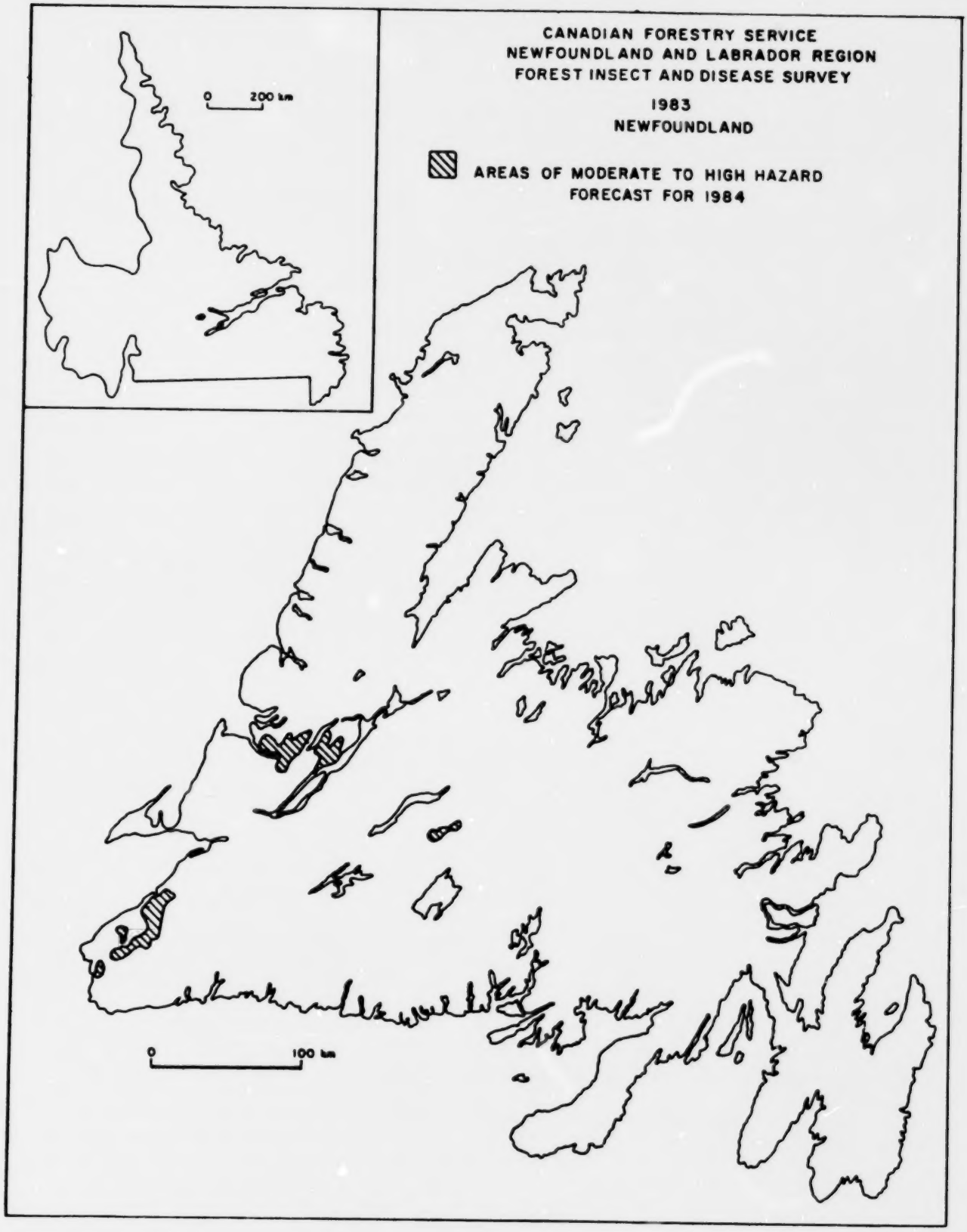

Figure 9. Areas of moderate to high spruce budworm hazard forecast in Newfoundland and Labrador for 1984.

Moderate and severe defoliation was expected on 55 000 ha and an additional area of 81 000 ha was forecast to be lightly defoliated for a total of 136 000 ha for 1984. Much of this area has already been severely damaged and 80 000 ha were classed as moderate to high hazard for 1984.

III. THE SPRUCE BUDWORM IN 1984

A. Outbreak Details

a) Larval Development

Cool, wet weather was prevalent throughout most of June and larval development was delayed by about two weeks, compared to 1983 and also a few days behind a long-term average. Several nights of frosts occurred in many budworm infested areas between June 16 and 26, causing prolonged periods of inactivity by larvae. Larval counts continued to remain up to 25 per 45 cm branch in high population areas, but few late instar larvae were observed to feed. Many areas of high initial larval counts failed to cause severe defoliation because larval populations collapsed.

b) Natural Control Factors

Spruce budworm larval and pupal populations were sampled in infested areas in 1984 to determine rates of parasitism and the prevalence of diseases. Forest Insect and Disease Survey rangers sampled in all districts with infestations several times in the year. Average parasitism in their samples of 663 budworm was 18% with another 40% of unexplained mortality (Table 6); which includes percent disease. A total

Table 6. Results of FIDS spruce budworm rearings in Newfoundland in 1984.

FIDS district	Total No. Reared	No. moths emerged	No. parasitized	No. missing & dead by misc.	No. diseased & dead by unknown causes
White Bay	111	47	31	0	33
Humber	225	88	57	0	80
St. George's	327	149	29	0	149
Total	663	284	117	0	262
% of Total		42	18	0	40

of 1,700 larvae were reared for research purposes. Of these 11% were parasitized, about 1% died of fungal disease and the cadavers of another 1% contained the sporidian disease, Nosema fumiferana. The same parasite species that have predominated since the beginning of the outbreak predominated again, Apanteles fumiferana and Glypta fumiferanae in the larval stage and Phaeogenes hariolus and Ephialtes ontario in the pupal stage.

c) Moth Flight

Pheromone baited traps were placed only in twelve selected sites used for budworm research. At these sites all moths trapped could have been local moths and no evidence of moth transport from mainland Canada into Newfoundland existed. Trap catch was in direct proportion to June-July larval populations indicating only local moths were caught.

d) Defoliation Estimates

The annual aerial survey began on 24 July after all feeding by the budworm was completed. The area of moderate and severe defoliation was 15 300 ha with 7 300 ha in the light category, a decrease from 68 000 ha and 32 000 ha in 1983 respectively (Table 7). Most areas of defoliation were in western Newfoundland with isolated patches of infestation occurring in the Codroy Valley, Big Falls and on the Baie Verte Peninsula. An infestation also occurred along the Noel Paul's Brook in central Newfoundland (Fig. 10). In Labrador the infestation collapsed and no defoliation was recorded. Only two areas of infestation remained in central Newfoundland, along Noel Paul's Brook and on the Baie Verte Peninsula, and none in eastern Newfoundland.

Table 7. Area (ha) of defoliation caused by the spruce budworm in productive forests of Newfoundland in 1984.

Management Unit No.	Defoliation Class[1]			
	Light	Moderate	Severe	Total
9	2 400	-	3 600	6 000
12	800	300	2 700	3 800
14	400	-	6 900	7 300
15	3 700	700	1 100	5 500
Total	7 300	1 000	14 300	22 600

[1]Light - 1-25%
Moderate - 26-75%
Severe - 76-100%.

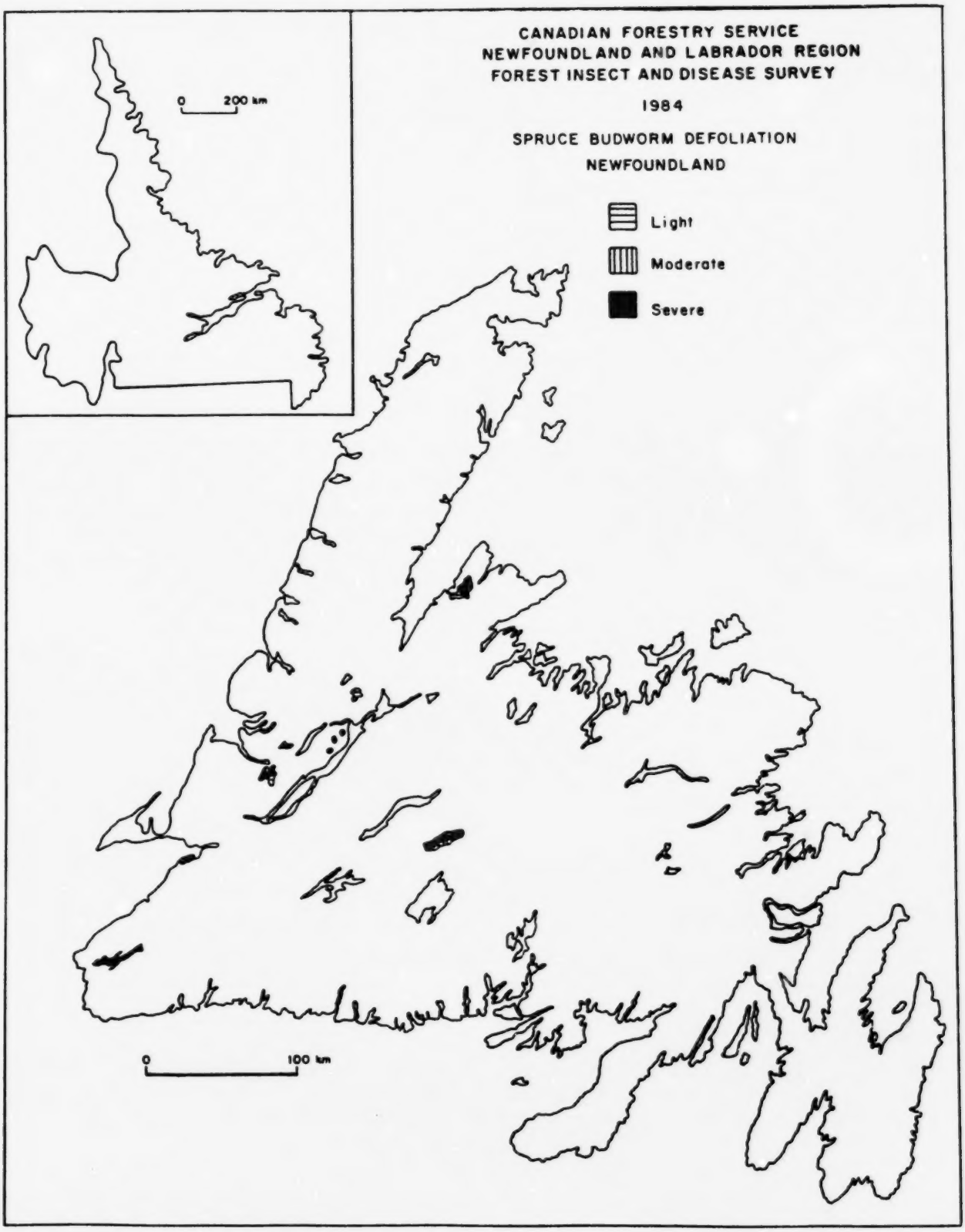

Figure 10. Areas of light, moderate and severe spruce budworm defoliation in Newfoundlnad and Labrador for 1984.

B. Damage Assessment

Traditionally the Forest Insect and Disease Survey assessed and reported damage and tree mortality areas and volumes at the 1:250 000 scale. This assessment was intensified in the past four years jointly with the Inventory Section of the DFRL using 1:50 000 and 1:30 000 scale maps to facilitate the use of the data at the forest inventory level to plan salvage operations. The DFRL collected damage data at this scale in 1984 and the staff of that Department will report this information. However, less intensive surveys by the Forest Insect and Disease Survey showed no increase in areas with more than 10% tree mortality from the 389 000 ha of balsam fir stands and 96 000 ha of black spruce stands reported for 1983 (Table 3). The total volume of these stands was estimated at 40 441 000 m^3 and 10 322 000 m^3 respectively.

Mortality rate of black spruce associated with the four-eyed spruce bark beetle decreased from an average of 8.7% in 1983 to 4.5% in 1984. The corresponding decrease in immature black spruce was from 5% to 2%. Trees in defoliation classes, ranging from 10% to 90% were successfully attacked by this bark beetle. In addition, several trees were attacked in 1984 that had died during the winter of 1983 to 1984. Trees with bark beetles were not concentrated in the most severely damaged trees as they were in 1983. Even in young stands, where only 2% of the trees had died, trees with various degrees of defoliation were successfully attacked.

The decrease in the rate of black spruce mortality from 1983 to 1984 is consistent with other observations indicating a decline of bark beetle activity and possible recovery of surviving spruce trees. Stands of various damaged classes will be monitored to document the role of the bark beetle and root rot in the future development of these stands.

C. THE SPRUCE BUDWORM SPRAY PROGRAM

a) Spray Operations

The Newfoundland DFRL sprayed a total of 23 226 ha with aminocarb (= Matacil), 2 390 ha with the B.t. formulation Dipel 132 and 720 ha with the B.t. formulation Thuricide 16B, for a total of 26 336 ha (H. Crummey 1984, unpublished report) (Fig. 11). About 94% of the aminocarb-sprayed areas received two applications of 70 g ai/ha in 1.46 ℓ/ha each. Both B.t. sprays delivered 20 BIU/ha with 23% of sprayed areas receiving two applications because of rain following the first application. Dipel 132 was sprayed in 1.57 ℓ/ha and Thuricide 16B in 7.0 ℓ/ha.

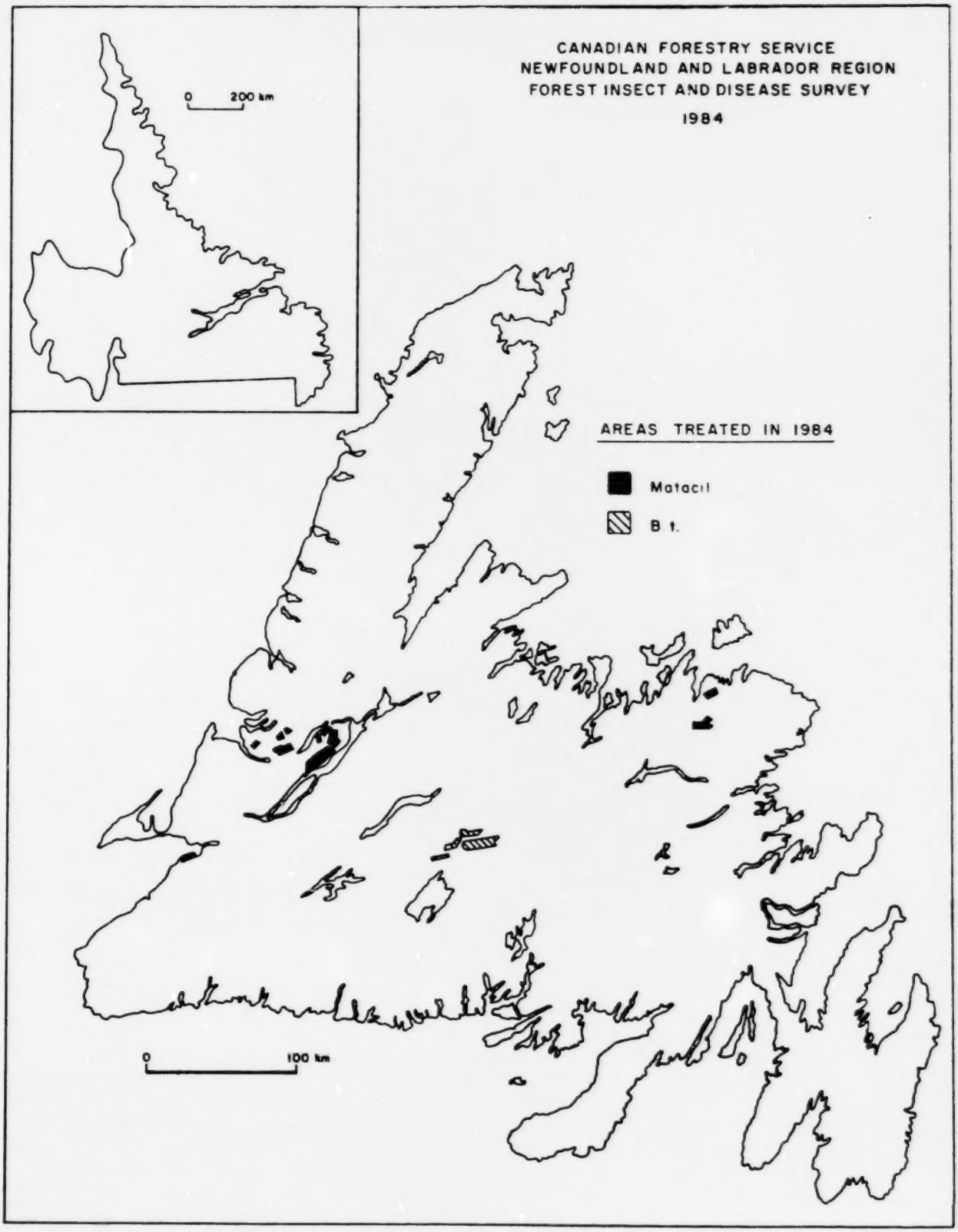

Figure 11. Areas sprayed against the spruce budworm in Newfoundland in 1984.

As in 1983 pre-spray population levels were very variable within and between spray blocks, with only a few areas of very high populations of 13-53 larvae per 45 cm branch. Two teams of three AgCats each started spraying on 21 June and the spray program was completed on 6 July. One team was equipped with Boom and Nozzle with 80-04 Tee Jet tips and the other with an AU 5000 Mini-Micronair system.

The spray program was successful in reducing larval numbers. Corrected larval mortality ranged from 85% to 100% for the B.t. sprays and from 98% to 100% for aminocarb sprays. Foliage protection was, however, variable ranging from 28% to 55% for B.t. and 63% to 89% for aminocarb. From aerial defoliation assessments 98% of all treated areas were classed light, and 1% each as moderate and severe (H. Crummey, 1984 unpublished report).

b) Environmental Monitoring

In 1984 the environmental monitoring program on non-target organisms focused on monitoring stream fauna of large insect species and on the flora of algae attached to stream substrates. Both were measured in dry weight biomass (Anon. 1986b). Estimates of biomass were obtained of drift, the short term impact, of bottom dwellers, the intermediate range impact, and of algae, the long-term impact.

As in past years there was no difference in drift in 1984 between sprayed and control streams in magnitude or in seasonal pattern.

The biomass of the stream bottom of the brook that had never been sprayed had significantly higher biomass than the other three. The stream that had been sprayed annually since 1981 continued to have reduced biomass as in previous years. The stream that had not been sprayed in 1981 to 1983, but was sprayed for the first time in 1984 had an unusually low biomass during and following the spray period. Finally, the stream that was sprayed in 1981, 1982 and 1983 but not in 1984 had an increased level of biomass following the spray period than it had in 1981 to 1983. Thus the 1984 data provided evidence for a limited impact of Matacil on macro-invertebrate biomass on the stream bottom; lasting for at least one season. The evidence suggests that one year of spray may reduce the quantity of insects in streams, and these quantities are restored the first year after a spray.

D. FORECAST OF BUDWORM INFESTATIONS FOR 1985

Spruce budworm egg-mass numbers were surveyed in 1984 by collecting branches from 281 locations, primarily in western and central Newfoundland. The branches of 35 locations were washed in a sodium hydroxide solution for overwintering larvae to refine boundaries of infestations. All samples were checked by a second person.

The total area of light, moderate and severe defoliation is forecast to be about 63 100 ha for 1985 (Table 8). Potential moderate

Table 8. Spruce budworm defoliation (ha) forecast in productive forests of Newfoundland for 1985.

	Defoliation Class[1]		
Unit no.	Light	Moderate and severe	Total
9	-	15 900	15 900
12	-	7 400	7 400
14	13 000	4 400	17 400
15	6 200	-	6 200
16	14 600	1 600	16 200
Total	33 800	29 300	63 100

[1]Light = 1-25%
Moderate and severe = 26-100%.

and severe defoliation is forecast for about 29 300 ha distributed in isolated areas in the Codroy Valley, near Sandy Lake and Baie Verte in western Newfoundland and in the Noel Paul's River Valley in central Newfoundland (Fig. 12). Light defoliation is forecast to occur in the Codroy Valley, near Corner Brook, Deer Lake, in the Upper Humber River Valley and in the Baie Verte area in western Newfoundland and near Badger in central Newfoundland. The infestation in Labrador collapsed this year and no defoliation is expected for 1985.

A total of 94% of the branch samples had no egg-masses, 34% had no overwintering larvae in 1984, and 96% of the samples occurred in areas forecast to have nil or light defoliation.

The average number of egg-masses per 10 m^2 of all locations has been used as an index of spruce budworm population levels since 1978 (Table 12). This index, averaged for all regions, continued to drop to three in 1984 down from four in 1983. Those locations with sufficient egg-masses to forecast moderate and severe defoliation were again few and they had about the same egg-masses per 10 m^2 of foliage as in 1983 (Table 13).

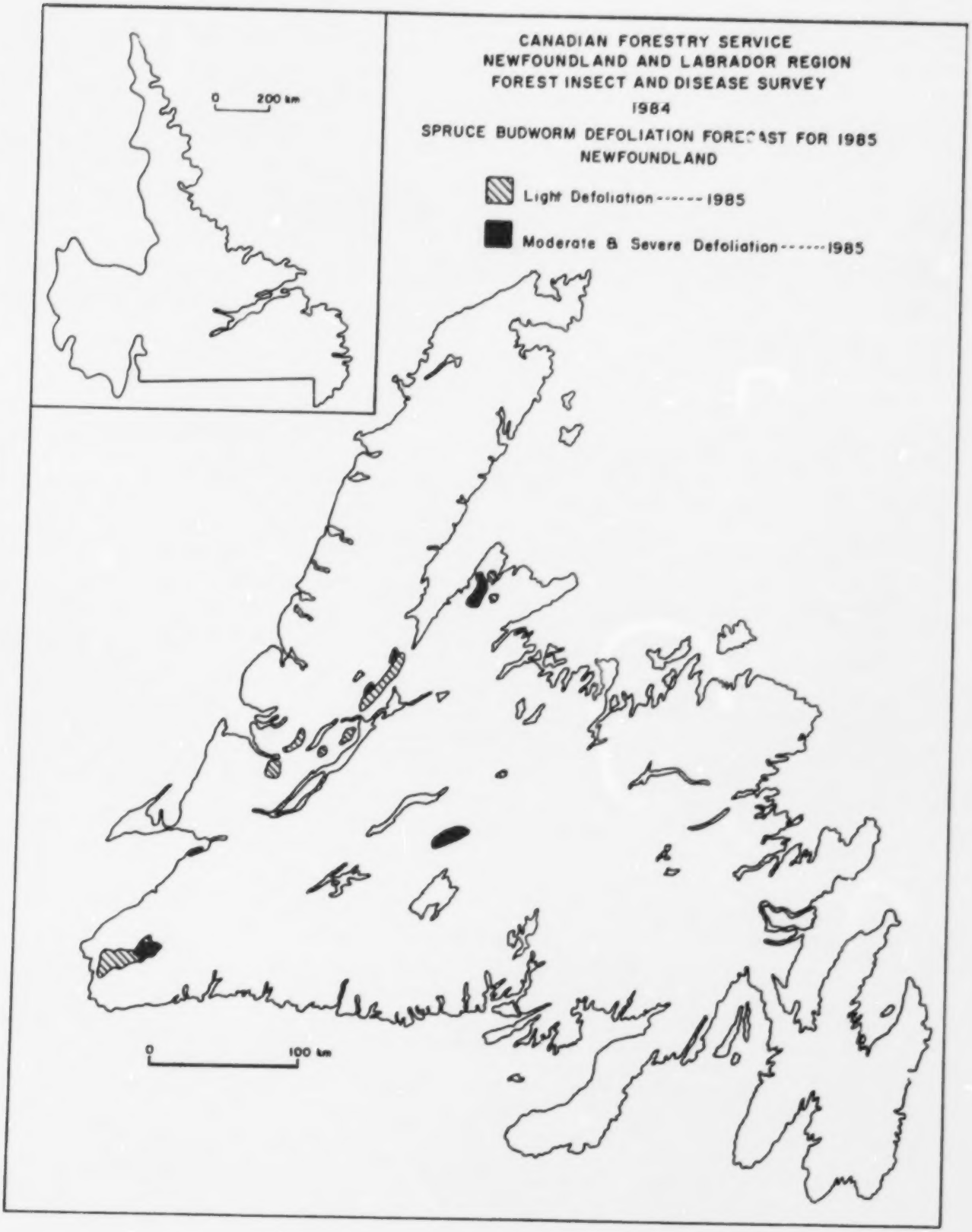

Figure 12. Areas of light, moderate and severe spruce budworm defoliation forecast in Newfoundland and Labrador for 1985.

E. SUMMARY AND CONCLUSIONS FOR 1984

A total of 135 600 ha of spruce budworm defoliation could have been expected to occur in Newfoundland in 1984 of which 55 200 ha was expected to be moderate and severe. About 80 000 ha of the total was classed as moderate to high hazard. Cool wet weather was common in July and larval development lagged behind that of 1983 by about two weeks.

Parasitism of the spruce budworm was 11% and 18% in two sets of samples, about 1% was killed by fungi and another 1% was infested with microsporidia.

The total area of light, moderate and severe defoliation in productive forests of the Island was about 22 600 ha of which 15 300 ha were in the moderate and severe categories.

The total area and volume of dead and damaged stands changed little from that present in 1983.

A total of 23 226 ha were sprayed with aminocarb (= Matacil) and another 3 710 ha with B.t. Larval population reduction varied from 85% to 100% for B.t. and from 98% to 100% for aminocarb. Foliage protection varied from 28% to 55% for B.t. and from 63% to 89% for aminocarb.

Potential moderate and severe defoliation was forecast to occur on 29 300 ha and 33 800 ha was expected to have light defoliation in 1985.

IV. THE SPRUCE BUDWORM IN 1985

A. Outbreak Details

a) Larval Development

Early spring and summer weather was seasonally warm and sunny except along the south coast where fog and cooler temperatures were frequent. Larval development was a few days ahead of that in 1984 and about equal to the long term average. Larval feeding was essentially completed by mid-July.

b) Natural Control Factors

Forest Insect and Disease Survey rangers sampled spruce budworm larval and pupal populations in all infested areas in 1985 to determine rates of parasitism and the prevalence of diseases. Average parasitism in their samples was 17% with another 30% mortality was caused by diseases and unknown causes (Table 9). Larvae from several research plots

Table 9. Results of FIDS spruce budworm rearings in 1985 in Newfoundland.

FIDS district	Total No. Reared	No. moths emerged	No. parasitized	No. missing & dead by misc.	No. diseased & dead by unknown causes
White Bay	162	85	19	0	58
St. George's	74	41	22	3	8
Total	236	126	41	3	66
% of Total		52%	17%	1%	30%

were also reared. About 17% of these larvae were parasitized, about 1% died of fungal diseases and the incidence of microsporidian in dead larvae was less than 1%. All larvae with microsporidia were collected in one locality. The same species of parasites and fungi were dominant that were common in other years.

c) **Moth Flight**

A total of 30 permanent pheromone trap sampling locations were selected in 1985. Three pheromone traps were placed at these locations before moth emergence and collected after moth activity was over. Error in manufacture of the artificial lures caused many lures to have little or no pheromone, therefore results are inconclusive; i.e. negative trap catches does not imply lack of moths. Large numbers of males were trapped only in Sally's Cove and at Grand Lake (south of Pasadena), where about 1 000 and 2 000 moths were trapped respectively. Most locations had no moths and five had between one and thirteen moths. Larval populations in both sample areas of large moth catch were too low to cause defoliation discernable within the stand. Therefore, these moths may have been transported from other areas. The moths at Sally's Cove may have come from other Atlantic Provinces.

d) **Defoliation Estimates**

The annual aerial defoliation was delayed in 1985 to 22 August because the areas of defoliation by the budworm was small compared to that defoliated by the eastern hemlock looper (*Lambdina fiscellaria fiscellaria* (Guen.)). Therefore, defoliation by both insects was mapped at the same time.

Many of the remnant budworm infestations collapsed in 1985 and only four areas totaling 3 500 ha of defoliation remained on the Island, located near South Branch, Big Falls, Baie Verte in western Newfoundland and along Noel Paul's Brook in central Newfoundland (Fig. 13, Table 10). This is a decrease from the 22 600 ha recorded in 1984 and considerably less than the 63 100 ha of potential defoliation in the forecast. The large area of expected infestation expected near Big Falls collapsed in the early larval instars in June. The infestation near Noel Paul's Brook was treated with aerial application of B.t. and this may have prevented severe defoliation.

B. DAMAGE ASSESSMENT

Detailed assessment of damage at the inventory level is conducted by the DFRL. However, less intensive surveys by the Forest Insect and Disease Survey showed that the areas with more than 10% tree mortality did not increase from the 388 700 ha of balsam fir stands and the 95 700 ha black spruce stands reported in 1983 and 1984. The total volume of these stands was estimated at 40 441 000 m^3 and 10 322 000 m^3 respectively.

Table 10. Areas (ha) of defoliation caused by the spruce budworm in productive forests of Newfoundland in 1985.

Management unit no.	Defoliation Class[1]			
	Light	Moderate	Severe	Total
9	1 800	200	-	2 000
12	700	-	300	1 000
14	100	-	-	100
16	400	-	-	400
Total	3 000	200	300	3 500

[1]Light - 1-25%
Moderate - 26-75%
Severe - 76-100%.

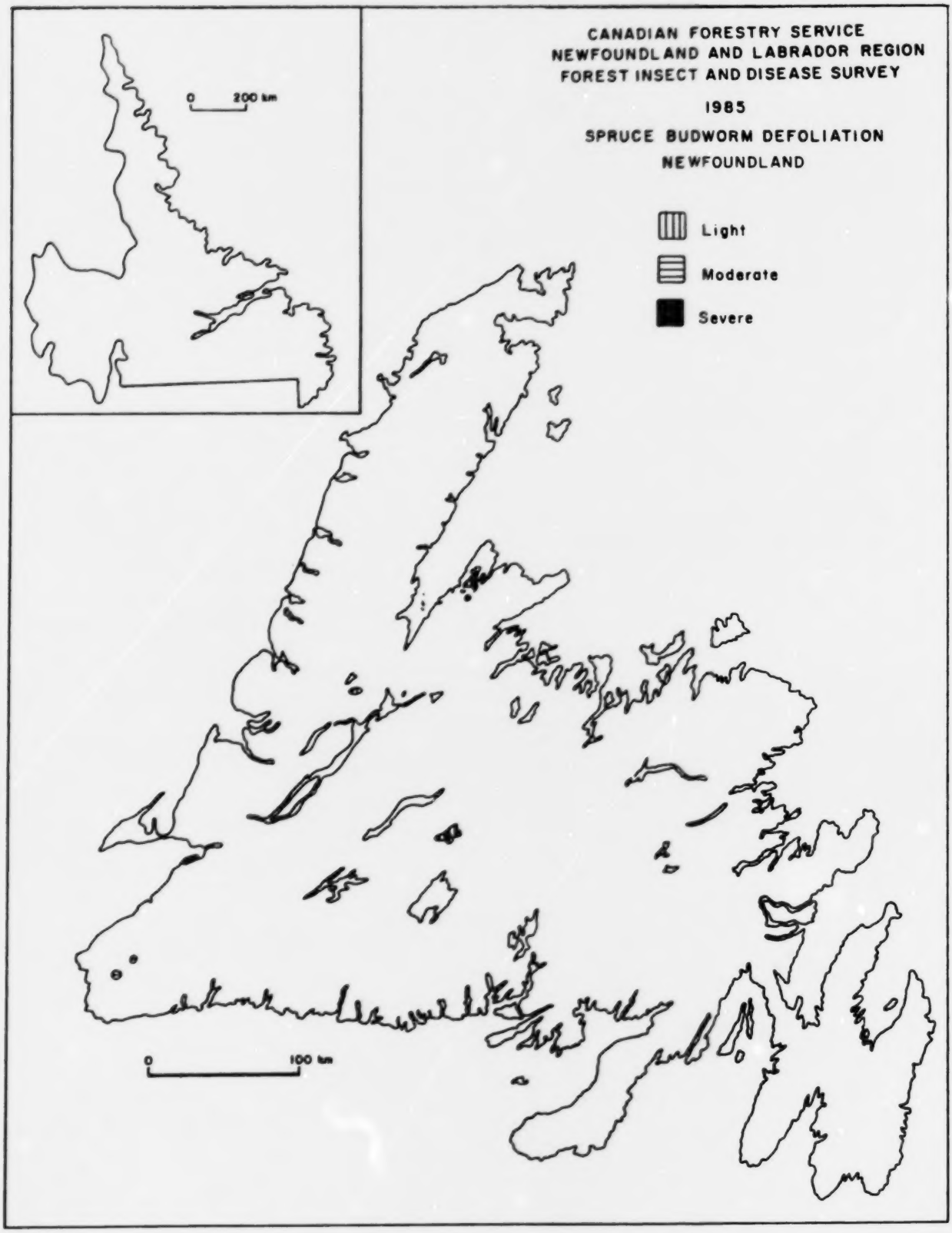

Figure 13. Areas of light, moderate and severe spruce budworm defoliation in Newfoundland and Labrador in 1985.

A significant portion of the damaged stands does not exist because salvage operations have continued throughout the outbreak. In addition, removal of dead timber by factors such as blowdown or advanced decay have also continued.

Mortality rate of black spruce associated with the four-eyed spruce bark beetle in the 12 permanent plots in mature black spruce decreased again in 1985, to an average of 3.2% from 4.5% in 1984 and 8.7% in 1983. The corresponding decrease in immature spruce stands were 1.2% in 1985, 2% in 1984 and 5% in 1983. Again in 1985 trees in 20% to 90% defoliation categories were successfully attacked by this beetle, and attacks were not confined to the more severely damaged trees. Even in young stands, where only 1.2% of the trees died, trees with various degrees of damage were successfully attacked.

The decrease in the rate of black spruce mortality from 1984 to 1985 is consistent with other observations of declining bark beetle activity and possible complete recovery of surviving spruce trees.

Many areas of damaged spruce stands have been salvaged. However, large areas of dead and damaged black spruce stands still remain in the Upper Northwest Gander River area and along the Bay d'Espoir Highway between the mouth of Miquel's Brook and Little Gull Pond in Upper Southwest Gander River near Dennis Brook, between Jumpers Brook and Rattling Lake, near Wooddale Nursery, Junction Brook near Badger, Powderhorn Lake, Sops Lake to Tommy's Arm and Nutmeg Hill to Three Corner Pond (Hall's Bay).

C. THE SPRUCE BUDWORM SPRAY PROGRAM

a) Spray Operations

The Newfoundland DFRL sprayed 2 945 ha with aminocarb (= Matacil) in the Gander area for experimental purposes only, and 3 450 ha with the B.t. formulation Dipel 132 for budworm control, for a total of 6 395 ha (H. Crummey 1985, unpublished report) (Fig. 14). All aminocarb blocks received two applications of 70 g ai/ha in 1.46 ℓ/ha each. B.t. sprays delivered 20 BIU/ha in 1.57 ℓ/ha in one application.

Pre-spray population levels were very variable within and between spray blocks, with only a few areas of high pre-spray population levels. One team of three AgCats aircraft was used and spraying started 27 June and was completed by 11 July. Each plane was equipped with six AU 5000 Mini-Micronair spray systems.

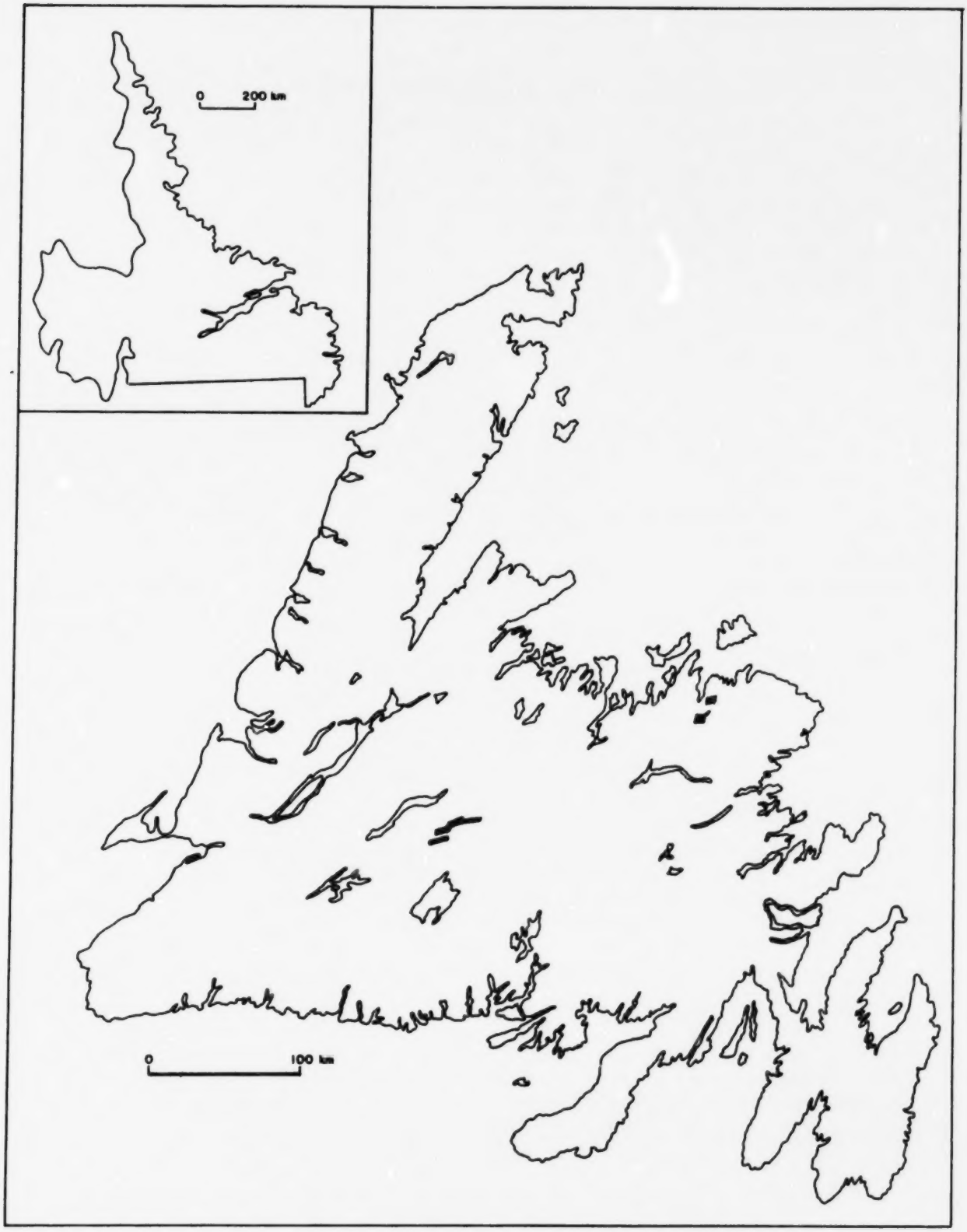

Figure 14. Areas sprayed against the spruce budworm in Newfoundland in 1985.

Average larval mortality was 60% and overall foliage protection averaged 36%. This low percentage was probably caused by the natural collapse of population and the late application of sprays.

b) Environmental Monitoring

In 1985 the environmental monitoring program was the same as in 1984, with emphasis on effects on aquatic communities, by measuring changes in biomass (Anon. 1986c). Again as in 1982, 1983 and 1984, there was no noticeable effect on the magnitude nor on the seasonable pattern of drift of aquatic insects in sprayed streams.

In 1984 there was evidence for limited impact on stream bottom macro-invertebrates. Biomass in a stream was reduced from that of previous years when the stream was sprayed for the first time in 1984. Also the biomass in a stream that had been sprayed previously increased decidedly when it was not sprayed in 1984. Conclusions drawn from the 1985 data is contrary to those drawn from the 1984 data. The biomass in the stream sprayed in 1984 and again in 1985 returned to its pre-1984 level when it was not sprayed, and the biomass in the stream not sprayed in 1984 and 1985 returned to its pre-1984 level when it was sprayed. The Newfoundland Department of the Environment in their executive summary of their report concluded: "It seems reasonable, therefore, to accept the null hypothesis that generally lower macro-invertebrate levels observed in Weir's Brook and Island Pond Brook was due to a pre-existing condition and did not result from the spruce budworm spray program." (Anon. 1986c).

Similar to past years' results, there was no effect of the spray program on the algal biomass in the sprayed streams.

D. FORECAST OF BUDWORM INFESTATION FOR 1986

Spruce budworm egg-mass numbers were surveyed in October of 1985 by collecting branches from ten locations in or near areas where defoliation had occurred in 1985. All samples were washed for overwintering larval numbers and all were checked by a second person. Stands in which many moths were observed near pheromone traps have also been included in the forecast for light defoliation.

The total area of defoliation forecast for 1986 was 7 500 ha of light defoliation and no moderate and severe defoliation was expected (Table 11). Defoliation was expected in four widely isolated areas; three in the west coast and one in central Newfoundland; on the Baie Verte Peninsula, Trout River, South Branch, and Noel Paul's Brook (Fig. 15).

A total of 80% of the branch samples had no egg-masses nor overwintering larvae in 1985, and all of the samples occurred in areas forecast to have nil or light defoliation.

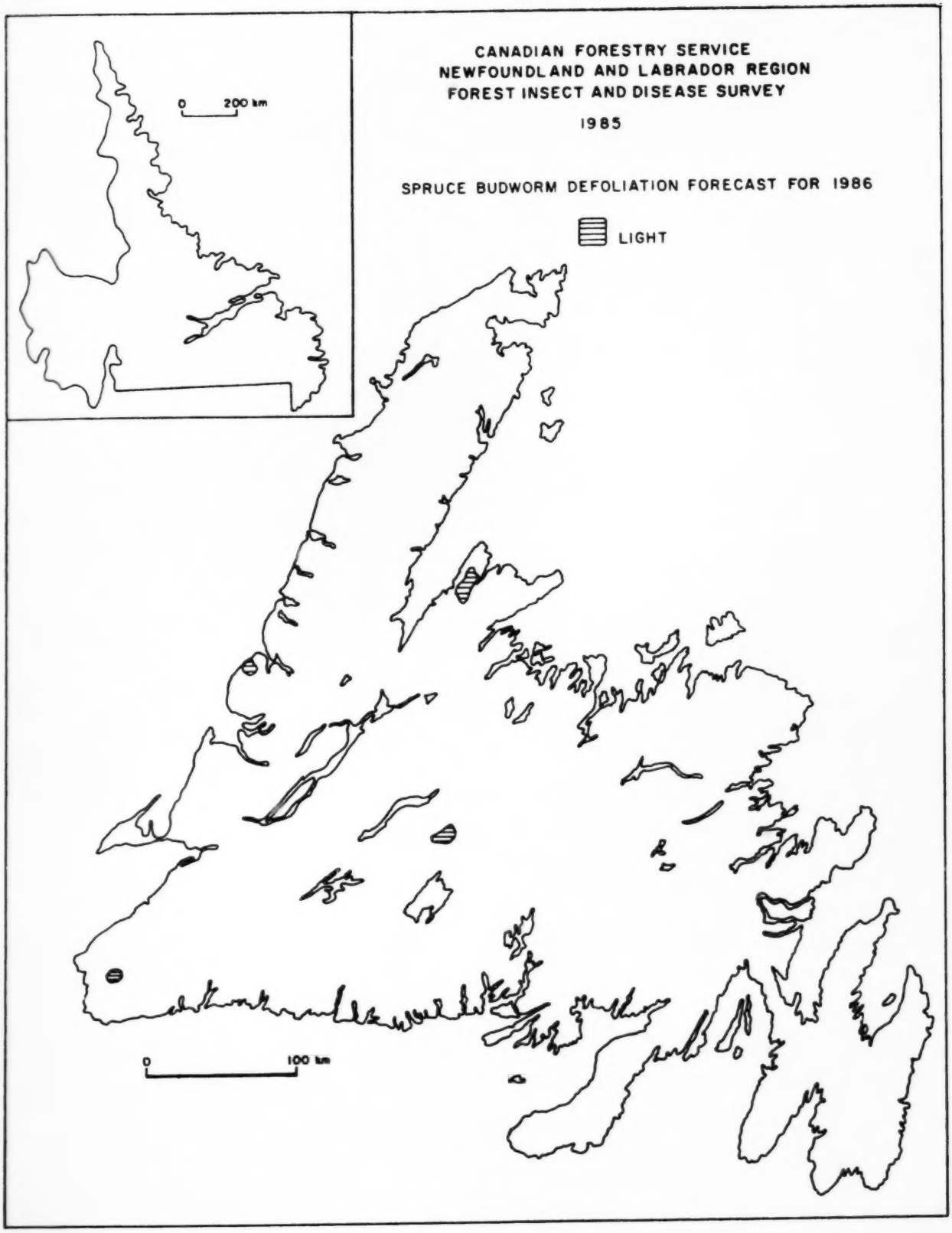

Figure 15. Areas of spruce budworm defoliation forecast in Newfoundland and Labrador for 1986.

Table 11. Areas (ha) of defoliation caused by the spruce budworm forecast in the productive forests of Newfoundland for 1986.

Management Unit No.	Ownership	Defoliation Class[1] Light	Total
9	Corner Brook P & P	5 500	5 500
12	Abitibi-Price	1 600	1 600
14	Corner Brook P & P	200	200
17	Crown	200	200
Total		7 500	7 500

[1]Light - 1-25%.

The average number of egg-masses per 10 m^2 of all locations has been used as an index of spruce budworm population levels since 1978 (Table 12). This index decreased to 2 in 1985, down from 3 in 1984. For the first time since before 1978 there were no sample locations with suffiicient egg-masses or overwintering larval numbers to forecast moderate or severe defoliation (Table 13).

E. SUMMARY AND CONCLUSIONS FOR 1985

A total of 63 100 ha of spruce budworm defoliation could have been expected to occur in Newfoundland in 1985, of which 29 300 ha was expected to be moderate and severe. Weather was near the long term average for much of the Island and similarly larval development, but a few days ahead of development in 1984.

Parasitism of budworm larvae and pupae averaged 17%, about 1% was killed by fungal diseases and another 1% was infected with microsporidia.

The total area of light, moderate and severe defoliation in productive forests of the Island deceased to 3 500 ha of which only 500 ha was in the moderate and severe category.

The area and volume of dead and damaged stands changed little from that reported for 1983. A total of 3 975 ha were sprayed with aminocarb (= Matacil) and another 3 645 ha with B.t. for a total of 7 620 ha. Larval population reduction averaged 74% for B.t. and 60% for the aminocarb. Foliage protection averaged 36%.

Table 12. Average number of spruce budworm egg masses per 10 m^2 from 1977 to 1985 in four regions in Newfoundland and Labrador.

	Mean Number of Egg Masses Per 10 m^2 Per Location							
	1977				1978			
Region	No. of samples	Mean	S.D.	Range	No. of samples	Mean	S.D.	Range
Western	432	92	181	0-1559	393	29	82	0-575
Central	315	204	296	0-2178	301	138	242	0-2255
Eastern	172	412	654	0-5080	160	192	243	0-1120
Total or weighted average	919	190			854	98		
	1979				1980			
Western	429	24	91	0-929	370	62	208	0-2308
Central	327	121	185	0-1222	291	97	195	0-2308
Eastern	158	213	237	0-1333	149	166	378	0-4116
Total or weighted average	914	91			810	94		
	1981				1982			
Western	278	8	38	0-453	316	16	-	0-2467
Central	335	9	55	0-833	343	1	-	0-522
Eastern	184	25	92	0-903	163	1	-	0-59
Labrador	10	0	-	-	20	3	-	0-395
Total or weighted average	807	14			842	7		
	1983				1984			
Western	349	6	-	0-1059	206	3	-	0-566
Central	238	1	-	0-335	75	4	-	0-324
Eastern	33	0	-	-	-	-	-	-
Labrador	15	1	-	0-44	-	-	-	-
Total or weighted average	635	4			281	3		
	1985							
Western	8	0	-	-				
Central	2	12	-	0-40				
Eastern	0	-	-	-				
Labrador	0	-	-	-				
Total or weighted average	10	2						

Table 13. Summary of spruce budworm egg-mass numbers per 10 m^2 of foliage for sample points with moderate and severe defoliation forecast in Newfoundland form 1978 to 1985.

Year	Moderate Defoliation Forecast*		Severe Defoliation Forecast*	
	No. sample points	Avg. EM/ 10 m^2	No. sample trees	Avg. EM/ 10 m^2
1978	72	154	124	491
1979	65	149	149	438
1980	49	149	123	437
1981	4	129	4	440
1982	10	147	7	379
1983	4	117	4	301
1984	2	157	1	324
1985	0	0	0	0

*Sequential limits for spruce budworm egg-masses/10 m^2 used for predicting defoliation:

No. of branches	Cumulative Number of Egg-Masses/10 m^2		
	Light**	Uncertain (moderate)	Severe
1	-	0-337	> 337
2	< 148	149-505	> 505
3	< 315	315-672	> 672

**Class limits of defoliation used for forecasting:

Nil - 0%
Light - 1-25%
Moderate - 26-75%
Severe - 76-100%.

Only light defoliation is forecast for 1986 to occur on four widely scattered areas totalling 7 500 ha. This forecast may indicate the termination of the spruce budworm outbreak that began in Newfoundland in 1977, however, localized areas of moderate and severe defoliation may recur.

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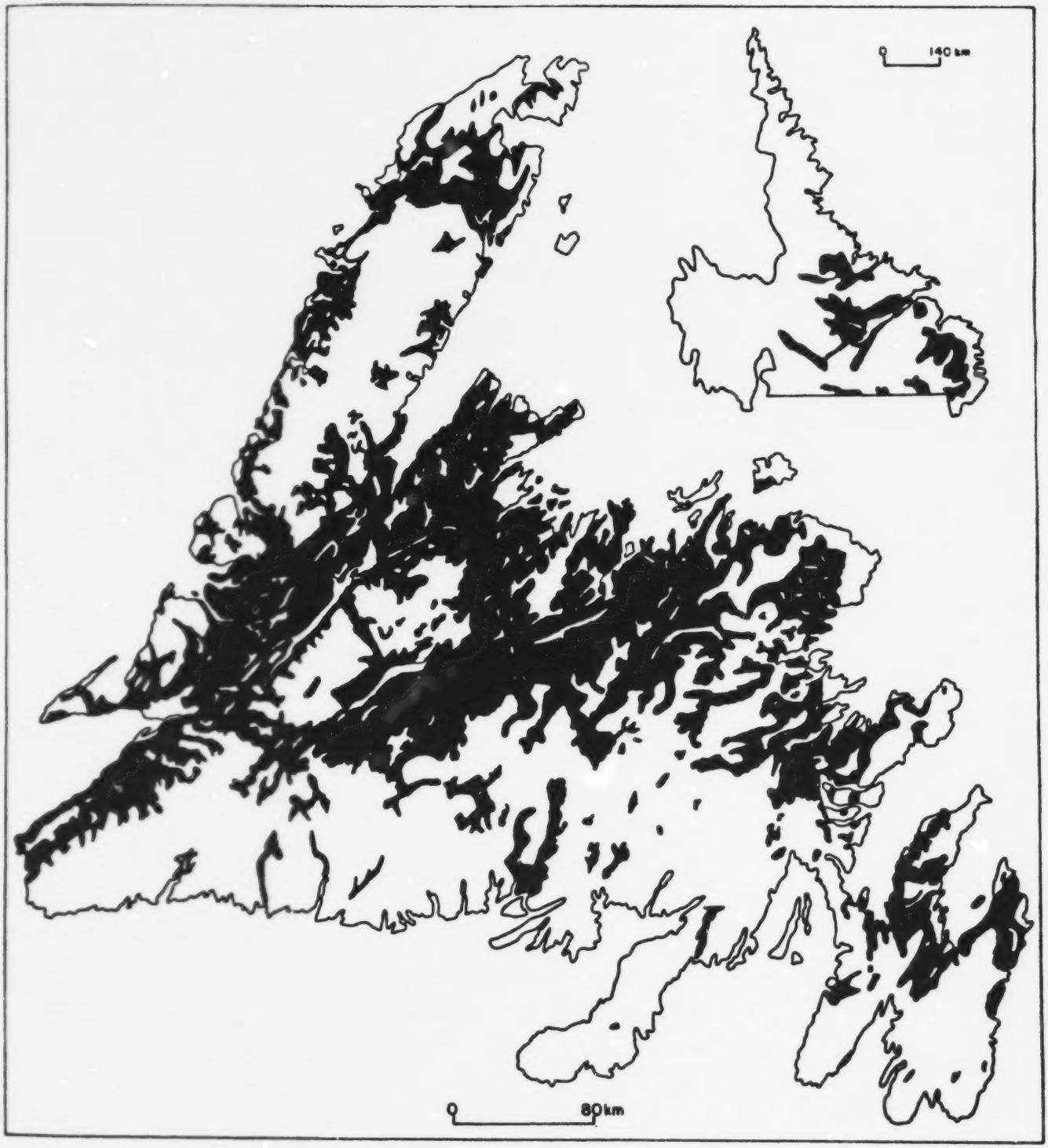
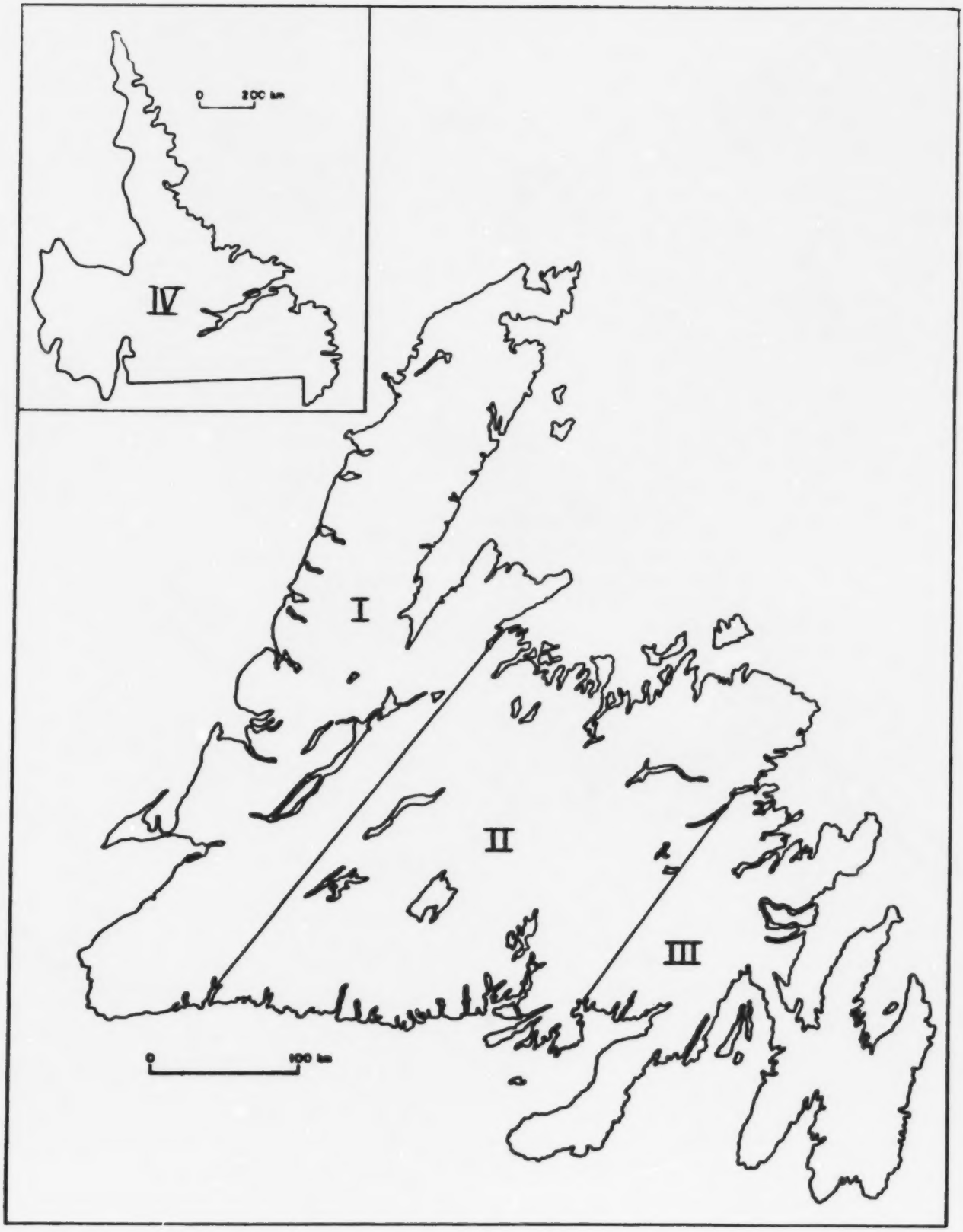
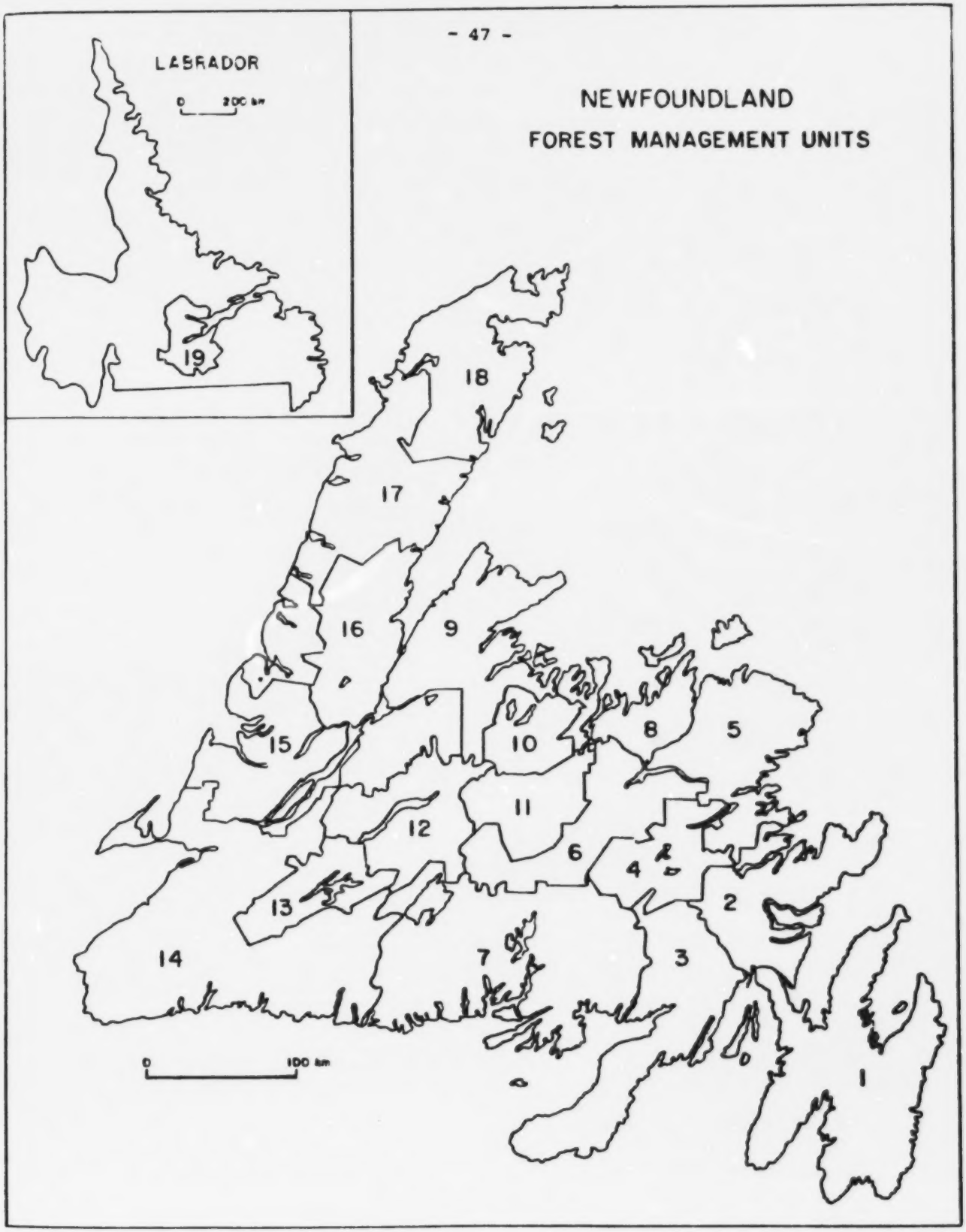
APPENDICES



APPENDIX I. Productive forest areas of Newfoundland and Labrador.



Appendix II. Major geographic regions of Newfoundland. I-western, II-central, III-eastern, IV-Labrador.



Appendix III. Forest Management Units in Newfoundland and Labrador.

Appendix IV. Numerical values of tree conditions and hazard rating system used to forecast losses in spruce budworm infested stands.

1. Current Defoliation

% Defoliation	Hazard rating
0	0
1 - 25	1
26 - 65	2
66 - 95	3
96 - 100	4

2. Old Defoliation or Previous Damage

Category	% Defoliation	Hazard rating
Zero	0	0
Light	1 - 25	3
Moderate	26 - 75	6
Severe	76 - 100	9
Dead tops	-	12 (optional)
Dead trees	-	15 (optional)

3. Tree Vigor

Category	Hazard rating
Dying	0
Poor	-1
Fair	-2
Good	-3

4. Egg-mass/10 m^2 of foliage

Category		Expected defoliation %	Hazard rating
0	Nil	0	0
1 - 106	Light	1 - 30	1
107 - 257	Moderate	31 - 65	2
258 - 429	High	66 - 90	3
430+	Very high	91 - 100	4

5. Sample Point Hazard Rating Categories for the Newfoundland Forestry Centre

Hazard rating	Range of total values	Remarks
Low	0 - 6	
Moderate	7 - 10	Protection suggested
High	11 - 14	
Very high	15+	Presalvage suggested

Appendix V. Number of egg-mass sample locations by predicted defoliation classes and geographical regions from 1977 to 1985 in Newfoundland. Numbers in parentheses are percentages based on total number of sample locations.

Year sampled	Region	No. points sampled	Number of Sample Locations in the Predicted Defoliation Classes			
			Nil	Light	Moderate	Severe
1977	Western	432	165(17.4)	157(16.5)	52(5.5)	58(6.1)
	Central	315	68(7.2)	108(11.4)	42(4.4)	97(10.2)
	Eastern	172	47(5.0)	38(4.0)	11(1.2)	76(8.0)
	Labrador	31	19(2.0)	8(1.0)	2(0.2)	2(0.2)
	Total	950	299(31.6)	311(32.7)	107(11.3)	233(24.5)
1978	Western	393	295(33.9)	70(8.0)	20(2.3)	8(0.9)
	Central	301	100(11.5)	105(12.1)	34(3.9)	62(7.1)
	Eastern	162	40(4.6)	44(5.1)	24(2.8)	54(6.2)
	Labrador	15	11(1.2)	3(0.3)	1(0.1)	0 -
	Total	871	446(51.2)	222(25.5)	79(9.1)	124(14.2)
1979	Western	430	340(36.2)	64(6.8)	15(1.6)	11(1.2)
	Central	327	146(15.6)	68(7.2)	35(3.7)	78(8.3)
	Eastern	160	40(4.3)	31(3.3)	26(2.8)	63(6.8)
	Labrador	21	19(2.0)	2(0.2)	-	-
	Total	938	545(58.1)	165(17.5)	76(8.1)	152(16.3)
1980	Western	370	264(32.6)	60(7.4)	13(1.6)	33(4.1)
	Central	291	166(20.5)	53(6.5)	19(2.4)	53(6.5)
	Eastern	149	52(6.4)	45(5.6)	14(1.7)	38(4.7)
	Labrador	0	-	-	-	-
	Total	810	482(59.5)	158(19.5)	46(5.7)	124(15.3)
1981	Western	278	229(28.4)	44(5.5)	3(0.3)	2(0.2)
	Central	335	311(38.5)	22(2.7)	0	2(0.2)
	Eastern	184	168(20.8)	15(1.9)	1(0.1)	0
*	Labrador	10	10(1.2)	0	0	0
	Total	807	718(89)	81(10)	4(0.5)	4(0.5)
1982	Western	316	251(29.8)	50(5.9)	8(0.9)	7(0.8)
	Central	343	336(39.9)	6(0.7)	1(0.1)	-
	Eastern	163	162(19.2)	1(0.1)	-	-
	Labrador	20	18(2.1)	1(0.1)	1(0.1)	-
	Total	842	767(91.1)	58(6.9)	10(1.2)	7(0.8)
1983	Western	349	276(43.5)	42(6.6)	-	31(4.9)
	Central	238	230(36.2)	1(0.2)	-	7(1.1)
	Eastern	33	32(5.0)	1(0.2)	-	0
	Labrador	15	11(1.7)	4(0.6)	-	0
	Total	635	549(86.4)	48(7.6)	-*	38(6.0)
1984	Western	206	179(63.7)	21(7.5)	-	6(2.1)
	Central	75	70(24.9)	-	-	5(1.8)
	Eastern	0	-	-	-	
	Labrador	0	-	-	-	
	Total	281	249(88.6)	21(7.5)	-	11(3.9)
1985	Western	8	7(70.0)	1(10.0)	-	-
	Central	2	2(20.0)	-	-	-
	Eastern	0	-	-	-	-
	Labrador	0	-	-	-	-
	Total	10	9(90.0)	1(10.0)	-	-

*Moderate and severe combined for 1983 and 1984.

Appendix VI. Average number of spruce budworm larvae collected in three regions of Newfoundland and Labrador from 1978 to 1985.

	BEATING SAMPLES*																BRANCH SAMPLES													
	No. of Trees Sampled (Location)**								Average No. Larvae Per Tree Sample								No. of Branches Sampled								Average No. Larvae Per Branch							
Region	78	79	80	81	82	83	84	85	78	79	80	81	82	83	84	85	78	79	80	81	82	83	84	85	78	79	80	81	82	83	84	85
Western	441	331	255	308	207	222	182	90	13	22	28	16	8.2	5.9	10.8	4.9	460	343	82	149	324	137	117	9	3.8	5.6	16	11.2	2.8	8.8	6.4	13.0
Central	172	157	143	129	215	39	6	3	26	43	69	22	0.4	0.8	0.3	0.3	69	87	181	140	6	-	-	-	14.1	22.1	8	6.3	0	-	-	-
Eastern	259	38	108	59	162	43	6	3	25	86	88	10	1.1	2.9	0.3	0.3	179	204	52	-	-	-	4	-	8.1	13.0	14	-	-	-	0.2	-
Island	872 (227)	526 (289)	506 (178)	496 (158)	584 (167)	304 (108)	194 (67)	96 (35)	19	33	52	17	3.3	4.8	10.1	4.6	708 (223)	634 (330)	315 (118)	289 (99)	330 (88)	137 (70)	121 (36)	9 (3)	6.0	10.2	10.9	8.8	2.8	8.8	6.2	13.0
Labrador	4 (2)	51 (17)	- -	- -	44 (17)	6 (2)	1 (1)	- -	6	0	-	-	0.2	0.7	11.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	876 (229)	577 (306)	506 (178)	496 (158)	628 (184)	310 (110)	195 (68)	96 (35)	19	30	52	10	3.1	4.8	10.1	4.6	708 (223)	634 (330)	315 (118)	289 (99)	330 (88)	137 (70)	121 (36)	9 (3)	6.0	10.2	10.9	8.8	2.8	8.8	6.2	13.0

*The 2 m x 3 m beating sheet and 1 m x 1 m beating tray.

**No. of locations sampled in parentheses.

Appendix VII. Areas and volumes of productive merchantable stands where tree mortality caused by the spruce budworm was evident in Newfoundland in 1983.

	Area (ha)	Dead volume (m^3)	Dying volume (m^3)	Total stand volume (m^3)
Cumulative area to 1983				
Balsam fir	388 700	19 905 000		40 441 000
Black spruce	95 700	3 194 000		10 322 000
Total	484 400	23 099 000	--	50 763 000
Salvaged by 1983				
Balsam fir	45 300			4 212 000
Black spruce	14 400			1 412 000
Total	59 700	--	--	5 624 000
Burned by 1983				
Balsam fir	6 100			562 000
Black spruce				
Total	6 100	--	--	562 000
Blown down by 1983				
Balsam fir	56 700			5 762 000
Black spruce	6 600			660 000
Total	63 300	--	--	6 422 000
Stands existing in forests in 1983				
Balsam fir	280 500	12 200 000	1 984 000	29 905 000
Black spruce	74 700	2 766 000	915 000	8 250 000
Total	355 200	14 966 000	2 899 000	38 155 000
Stands still salvable in 1983				
Balsam fir	280 500	8 150 000	1 984 000	25 855 000
Black spruce	74 700	2 510 000	915 000	7 994 000
Total	355 200	10 660 000	2 899 000	33 849 000